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Citation for the original published paper (version of record):

Nilsson, P. (2008)
Recognizing the needs - Student teachers´ learning to teach from teaching.
NorDiNa: Nordic Studies in Science Education, 4(1): 92-107

Access to the published version may require subscription.

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Permanent link to this version:
http://urn.kb.se/resolve?urn=urn:nbn:se:hh:diva-16674

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Recognizing the needs – Student teachers´ learning to teach from teaching

Abstract
This paper is based on an exploration of the ways in which primary science student teachers recognize and learn about issues that shape their own professional learning. The paper discusses different perspectives of "knowledgebase needed for teaching" and Shulman's concept of pedagogical content knowledge, and explores how elements of knowledge are to be recognized and further developed within primary teacher education. Primary science student teacher participants (n = 25) were stimulated to use portfolios as a tool to reflect upon situations within their six weeks teaching practice in pre- and primary schools in order to facilitate recognizing their knowledge needs. The results give an insight into what situations within the teaching practice that student teachers consider as important for their own learning to teach primary maths and science.

Introduction

There is little doubt that the complexity of teaching highlights the need for more extensive research into the relationship between the different elements that constitute teacher knowledge, and how these are developed during teacher education. For example, questions as "How do we provide student teachers with an adequate knowledge base for the complex task of teaching science?" and "How do student teachers manage to recognize their own [need for] knowledge for teaching?" become important within the context of teacher education. However, as we know from research (e.g. Lindahl, 2003) students often have a negative attitude towards school science. Further to this, research findings from the past 20 years indicate that students do not learn science. At the same time, several studies have shown that the science teacher is the most important factor in improving students´ achievement. Hence the preparation of science teachers is crucial for the future of science education (van Driel, Beijaard & Verloop, 2001). Indeed, teacher education program must be targeted at student teachers' needs to translate required knowledge into effective classroom practice. However, for a meaningful discussion about teacher knowledge, all aspects of the knowledge base needed for teaching (Shulman, 1986, 1987) must be considered.

The complexity of teaching points out the necessity for deeper research into the relations between the different elements that constitute teacher knowledge, and how these are developed and integrated during teacher education. In this new century, teacher education is beginning to be better

valued as an object of academic research (Korthagen, Loughran & Russel, 2006). Research on student teachers´ pedagogical content knowledge (PCK), (De Jong & Van Driel, 2004; Nilsson, in press) have emphasized the importance of student teachers´ framing and reframing of their practice (Schön, 1983, 1987) in order to gain new insights into *what* and *how* they perform teaching. Hence, student teachers need to be confronted with real classroom situations to reflect on, and learn from these concrete examples (Nilsson, in press). Further to this, 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 to pedagogical content knowledge. Therefore, it seems reasonable to suggest that teacher education programs need sophisticated approaches to teaching about teaching if they are to encourage a vision in learning to teach science. Further to this, the schools´ demands to continuously develop their educational programmes require teacher education programs to provide student teachers with skills in order to teach effectively. During their school based practice student teachers are trained to handle teaching situations. However, a big responsibility has been on the student teachers to recognize their own teaching needs, and to "bridge the gap" (Loughran, 1994) between their university courses and the real school practice.

The aim of this paper is to discuss perspectives connected to the "knowledgebase needed for teaching" and further explore how elements of knowledge are to be recognized within student teachers´ practice. The following research question formed the basis of the empirical study from which to discuss the perspectives connected to the "knowledgebase needed for teaching: "What knowledge within the teaching practice do student teachers recognize as important for their own learning to teach primary maths and science?" Some empirical evidence from student teachers´ portfolios during six weeks pre- and primary school based practice is presented. These data provide examples of what important aspects of their teaching primary student teachers are recognizing. The answer to this question is crucial to the pedagogy of teacher education (Loughran, 2006). Hence, the practices and processes highlighted in this paper help to inform the ongoing development of how to involve student teachers in constructing meaningful knowledge of the knowledge base for primary science teaching.

Epistemological issues on teacher knowledge – The notion of experience and reflection

It seems reasonable to suggest that by encouraging science student teachers to reflect on their own teaching they may well develop deeper insights into their understanding 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 a pedagogy of teacher education (Loughran, 2006). Dewey (1916/1966) described that learning was situated in different situations and not limited to one special situation. A person experiences a situation, 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. 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 that 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 way the quality of an experience is changed and we can call it a reflective experience (Dewey, 1916/1966). If we transfer this reasoning to the context of teacher education we can say that student teachers must get a possibility to reflect on failures and successes in order to acquire a higher metacognitive level and thus develop their knowledge base for teaching.

As noted earlier, *reflection* has developed a great deal of discussions in teacher education programs. 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). Studies into reflection illustrate how beginning teachers often experience tensions between their beliefs and their actions in the practice of teaching (Van Manen, 1995). 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. However "effective reflection" (Loughran, 2002) or "productive reflection" (Davis, 2006) allows teachers to develop and demonstrate a more complex view of teaching. Productive reflection was described by Davis (2006) as the integration of ideas about multiple aspects of teaching, such as learners and learning, subject matter knowledge, assessment and instruction. As teacher educators, we want our student teachers to *recognize* and see what factors that matters in a classroom. However, an effective tool to promote reflection among student teachers is the use of reflective portfolios, which will be further developed in the method section of this paper.

The knowledge base for teaching

Learning to teach is a complex process. 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 students' learning and, importantly, their own learning to teach (see for example, Berry, 2004; Chin, 1997; Feiman-Nemser, 2001). 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 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*. Those 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.

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 was a relatively small amount of research on teacher education. One explanation could be the complexity that characterized the teacher education. For example, as Kagan (1992) noted, "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). Korthagen et al. (2006) highlighted the importance of research on teacher education. They presented seven principles that shaped teacher education programs and practices in ways that were 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) stressed the importance of student teachers´ learning from experience and their building on 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). Student teachers´ experi-

ences 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). Therefore, actively researching their own practice might help student teachers to frame and reframe (Schön, 1983, 1987) their practice and to thereby gain insight into how they might better understand that situation and act within it.

Teacher knowledge literature refers to a host of words describing the knowledge base 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 product as well as the process that 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. "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.

The complex notion of Pedagogical Content Knowledge

The question of what makes PCK important and how it is recognized and developed, initiates an important discussion of what we actually know about 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 on 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 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 what knowledge bases needed for teaching do teachers possess. How should the teacher use the content to build on analogies, metaphors, examples and demonstrations in order to promote students´ understanding? In his first paper, Shulman (1986) first 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 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 infection 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). In his second 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 the specific subject. Shulman (1987) then went further to describe the process *pedagogical reasoning and action* in which the knowledge base for teaching is developed and used. Shulman (1987) considered that *pedagogical reasoning and action* was necessary if teachers were to transform their personal comprehension of subject matter into forms that are comprehensible to the students. Pedagogical reasoning, as explained by Shulman (1987), is a cyclical process in six stages; comprehension, transformation, instruction, evaluation, reflection and finally new comprehension. The final stage, new comprehension, is concerned with the learning that teachers achieve through experience and then add to their pedagogical content knowledge. Through acts of teaching that are "reasoned" the teacher achieves new comprehension, both of the purposes and of the subjects to be taught, and also of the students and the processes of pedagogy.

The exact relationship between PCK and the model of pedagogical reasoning and action was not clearly expressed by Shulman (1987) but could be transformed 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 if it is possible to provide the student teachers with "critical incidents" (Tripp, 1993) which help them in their recognition and identification of important issues for this development to occur. Thus, teacher educators need to engage student teachers in activities that create experiences and stimulate reflection.

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 of that, a lot of researches 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 is more about the sophisticated process of combining knowledgebases together for particular contexts in relation to classes, topics or other factors."

(p. 202). Therefore, instead of arguing about the definition of PCK it is important to focus on the processes that would be involved in the production 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 about 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). Magnusson et al. (1999) 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 students' learning, they must experience such learning environments themselves. Magnusson et al. (1999) defined a model composed of five parts: orientation towards teaching science, knowledge of science curricula, knowledge of students' understanding of science, knowledge of instructional strategies, and knowledge of assessment of scientific literacy. In their conception of PCK, a person's orientation towards teaching influenced the development of the other four components of PCK.

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 knowledges, the "spinning top metaphor" illustrates PCK as a dynamic construct which is not amenable to static representation and can only be "seen" in action (Bishop & Denley, 2007). This 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 knowledgebases together (Bishop & Denley, 2007).

However, across the views of PCK described above, what kind of PCK is relevant from the point of view of Swedish science teacher education and from the point of view of this paper? Except for giving support to the ideas of considering PCK as a dynamic knowledge generated in practice through "the capability of the teacher to be able to combine or blend the individual knowledgebases together" (Bishop & Denley, 2007, p. 9), there is also commonality in terms of three well recognized knowledge bases: Pedagogical Knowledge (PK); Subject Matter Knowledge (SMK); and Contextual Knowledge (CK). 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, PK 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 students in their classroom (Mishra & Koehler, 2006). Contextual Knowledge (CK) is strongly connected to PK and represents knowledge of school departments, traditions, behavior of students, 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 students. Therefore the 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 (Nilsson, in press), lack of SMK makes it difficult for student teachers to relate phenomena to everyday situations, but subject matter alone is not sufficient. Different knowledges need to be transformed.

Thus, from the point of view of this paper, 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. However, to what extent does teacher education promote effective reflective practice concerning student teachers knowledge base for teaching, which involves questioning assumptions and having "many ways of seeing? (Loughran, 2002, p. 39)" Hence, to *recognize* different aspects in a teaching situation and also to *interpret* the impact of those aspects become important for the development of a knowledge base for teaching (i.e. PCK).

To recognize the knowledge - Experts and novices in different contexts

As we know from research (e.g. Berliner, 2004) expert teachers operate in a qualitative different way than novices. 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 instruction. 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 (i.e. knowledge categories). Further to this, if you can get expert science teachers to articulate what they know about teaching, student teacher might be able to use those insights in their learning to teach. Research on expertise suggests the importance of providing students with learning experiences that specifically enhance their abilities to recognize meaningful patterns of information. Referring to Bransford, Brown and Cocking (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.

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 and 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 student, parent or teacher might recognize factors that identify what they consider as the "best teaching". But this must not necessarily mean

that they would be able to *teach* in the "best way". Underlying principles (Hughson & Boakes, 2002) connected to the knowledge base for teaching might be more difficult to recognize.

As a result of a long experience the wine expert has learnt to recognize different nuances, differ between two wines and even put words on and identify the difference. If we again transfer this reasoning to student teachers learning to teach, the ability of recognizing 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 to 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 a 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 need to recognize its good characteristics. To be able to develop your PCK you must learn to recognize which elements that builds it up. With this background PCK might be considered as a useful concept in order to analyze, describe and characterize the complex phenomena that is called science teaching. Although student teachers (novices) can not always identify their own needs it is through *recognizing* and *confronting* the difficulties and dilemmas of practice that the development of PCK is enhanced. 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. Also, a proper understanding of the sophisticated development of PCK with student teachers may support our thinking about what student teachers to learn, and what science teacher education needs to offer in order to effectively instruct them.

Data source and context of the study

Reflection in teacher education has become one of the guiding principles for professional development. In particular, reflection is seen as a tool to make explicit these often "tacit" conceptions that student teachers hold. It is assumed that reflection and analysis of the practice of teaching might help student teachers to identify their needs both in improving what they already know and in recognizing what they do not know. For that reason reflection plays an important role in the construction of a knowledgebase needed for teaching (i.e. PCK). Therefore in the present paper reflective portfolios (Loughran & Corrigan, 1995; Mansvelder-Longayroux, 2006) have been used to document student teachers´ experiences and to get an insight into what they recognize as important aspects within the teaching practice.

During a six weeks period in their third term, 25 student teachers had their practicum in preschools and primary schools. They were undergoing a three-and-a-half year educational course, of which one year focused on teaching maths and science to students aged one to eleven. During the year the student teachers had taken four basic courses (eight weeks each) of mathematics, physics, chemistry and biology. Their six weeks of school practicum was aimed to give them an opportunity to use their scientific knowledge in a pre- and primary school context, thus they were told to teach maths and science as much as possible.

The reflective portfolio was used during their practicum as an instrument to encourage the student teachers to reflect on themselves as beginning teachers and on critical incidents within the practice (Tripp, 1993) that they considered had impact on their learning to teach. Portfolios can provide an organized tool for student teachers to document and describe their teaching, articulate their professional knowledge and to reflect on what, how, and why they teach (Mansvelder-Longayroux, 2006). Shulman (1992) highlighted the importance and need for portfolios in teacher education when he contended that portfolios were a strategy that allowed student teachers to capture the complexities of teaching and learning and their own learning to teach. As described by Loughran and Corrigan (1995), reflective portfolios offer insights into both the behavior and the knowledge acquisition of teachers and hence contribute to a professional learning. The portfolio is intended

to give a picture of both teachers´ practical knowledge and their behavior encouraging them to engage in professional self-development. "In preservice teacher education programs the teaching portfolio offers opportunities for student teachers´ experiences, thoughts, actions, and subsequent learning about teaching to be documented." (Loughran & Corrigan, 1995, p. 565).

The student teachers were told to everyday document (a) their goals with the teaching and how these were achieved, but also (b) their feelings and specific incidents within the teaching practice that they considered as important for their own learning to teach. Hence the portfolio provided a means for reflection; it offered an opportunity for critiquing their work and evaluating the effectiveness of lessons or the interactions with the students or the mentors. As the aim of the study was to explore how elements of knowledge (which impacts on PCK) were to be recognized by the student teachers within their practice, the student teachers were not told about the concept of PCK. Hence, the focus of reflection came to be the student teachers´ own personal stories about their behavior in the classroom, their problem solving and on pupils' behavior. In that sense it was assumed that working on the portfolio should enable the student teachers to visualize their experiences and further learning processes in concrete terms, to illustrate their [need for] PCK using information about their teaching practice and to think about their learning in a focused and structured way (Wolf & Diez, 1998). Hence, another intention with the writing in the portfolios was that when thinking about their practice, the student teachers would make explicit *what* experiences had been important learning experiences for them over a period of time and over different contexts. Those experiences might then be connected into an organized whole (Loughran & Corrigan, 1995).

Analysis and results

In order to give some empirical example of how the student teachers experienced their teaching practice, illustrative examples from the student teachers´ portfolios will be presented below. This section is not meant to analyze the student teachers´ *development* of PCK, neither to generalize nor compare the student teachers´ abilities to reflect, but rather to give some examples of how student teachers might interpret their teaching experiences and what learning that they consider coming out of these interpretations. Therefore a major focus of the reflective portfolios was to help the student teachers to articulate their understanding of what they think it means to be a primary science teacher. Hence, the presentation of the results concerns the elements of knowledge within the teaching that student teachers recognized as important for their knowledgebase for teaching.

After the six weeks of practice the 25 student teachers´ portfolios were collected for analysis. The 25 portfolios (in all about 300 pages) were read in order to get an overview of the whole group's experiences. The portfolios then became the basis for a descriptive analysis of how the student teachers experienced their practice. The data analysis started with a content analysis (Miles & Huberman 1994) where all the 25 portfolios were read repeatedly in order to identify recurring themes and produce thick descriptions (Geertz, 1973) of what situations the student teachers emphasized within the teaching practice. According to Miles and Huberman (1994) this kind of content analysis facilitates the production of *core constructs* from textual data through a systematic method of data reduction (selecting and simplifying from the entire data), data display (illustrate the patterns and findings within the data), conclusion drawing and verification (developing an initial thought about patterns and explanations from the findings and verifying them constantly by checking the data). In the data reduction, data were coded for recurring themes and illustrative examples within their experiences that the student teachers recognized and highlighted as important for their development of a knowledgebase for teaching. Next, some quotations that were representative of the categories that emerged from the data were selected. These aspects where grouped into *three main categories* **1)** Recognition of elements of knowledge needed for classroom teaching; **2)** Recognition of elements of knowledge needed for conflicts with students as well as

between students; and **3)** Recognition and identification of the students´ learning in a way that influenced their own ideas about teaching. Below, these three categories are illustrated with the student teachers´ graphic descriptions.

1. Recognition of elements of knowledge needed for classroom teaching

The student teachers´ limited experiences of teaching made them recognize several elements of knowledge needed for their classroom teaching practices (have clear instructions, to have sufficient subject matter knowledge and be well prepared). The student teachers also highlighted elements such as knowledge about scientific concepts and their meanings and issues concerning students´ motivation and attitude. As such, Tina referred to a situation when she did not remember how to explain her demonstration. She also referred to the importance of knowing how to handle students´ questions and to always rasp the moments within the teaching:

> Tina: Today I choose to demonstrate the experiment on air myself as I wanted it to be calmer than last time when they did the experiment. Well, I felt quite stupid as I did not have the time to try the experiment before and I know it was not good. We sat in a circle on the floor and everyone wrote their hypothesis. I had a bottle of lemonade, a funnel and then I poured some water in it. The first time it failed and I said too everyone that I probably poured too slowly, but the second time I managed and the water could not go into the bottle because of the air in the bottle. But at that time I was totally confused and I could not manage to explain the air pressure. But then suddenly I thought that it might perhaps be something with the surface tension and I poured some washing-up-liquid in it and it turned out to be really cool and the children asked a lot of hypothesis and came up with several good explanations.

In her portfolio Sandy wrote about how her experience during the lesson made her recognize several different aspects important for her teaching. She highlighted the complexity and difficulties concerning classroom management and how to maintain students´ interest and not give them all the answers directly. She also emphasized the importance of having enough subject matter knowledge and the ability to transform it to the student. Further to this she stressed the ability to read the students body language:

> Sandy: Today my lesson was a chaos! It is a tricky thing for a teacher to manage to be enough clear but not to give the students too much information on a too high level so that they become bored or that I kill their excitement. If it is too difficult or too easy the students loose their concentration. Still I want them to learn the scientific concepts. I want them to recognize them in the future. Today I also saw the importance of using all the senses while you are teaching. I mean it is easy only to listen to what the students are saying, but also to see their body language and to feel their pleasure and anxiety.

Sandy referred to her own inquiry of how to respond to students´ comments and questions in a proper way without loosing the intentions of the lesson. She recognized the importance of being flexible and open-minded for the students´ questions. Helen recognized the importance of handling different situations in the classroom and to try several teaching methods in order to promote students´ learning. She also recognized the need for her to walk around and discuss with the students in order to get an insight into their ways of thinking and acting and to see what they understand and don't understand. In summary the student teachers recognized several aspects within their teaching practice that they stressed as important for their teaching and learning to teach.

2. Recognition of elements of knowledge needed for handle conflicts with students as well as between students

The demands of the tough school climate made almost all of the student teachers to recognize their knowledge need for handling conflicts with students during teaching and also between students.

Julia recognized how the students seemed to like the experiments but not the writing. She also recognized several issues concerning the students´ relations and her own role as a leader that she stressed as important for her own earning to teach:

> Julia: Today I let the students do experiment on ice to see what happened with the water when you put it into the refrigerator. I have noticed that some of the students do not like to write hypothesis and now I have realized that it is not the experiments that bores them but the writing. I also noticed that some of the students find it hard to co-operate. It has become clear to me that as a teacher you always have to solve conflicts. I think that it is frustrating that the lesson continues and there are a lot of students that need help and at the same time I have to be there solving a conflict between two students that were fighting. I asked my self the question: How should I get the students to respect each other and to co-operate? I feel like a fire-extinguisher walking around extinguishing the fires all the time and it requires a lot of the strength of me and my students.

Tina recognized the importance of being able to deal with the students´ conflicts and to create a good classroom environment. However, she recognized the complexity in the teaching situation as students´ interests varied a lot:

> Today my lesson was a catastrophe. I was very well prepared, but the situation in the class was really chaotic. Some of the students decided to do other things during the same time as I was talking and they were really trouble makers for the others who tried to listen. I had a good dialogue with some of the students but then this discussion was interrupted I needed to tell the others to be silent. When I think about the lesson now, I would probably have needed to be clearer in my instructions and more definite towards some of the students. I mean, I was so chocked that they did not listen to me and some of them even started to fight. I am really thinking about how to create a good classroom environment.

In her portfolio Maria recognized her need to know how to handle a "messy" group of students and in some way manage to find order in the chaos. She also recognized the need to value the positive things in her lessons and not only focus on things that did not turn out to be as she expected. However, she stressed that she had learnt…and had been surprised by a lot of things about the students´ behaviour but that it was very important for her to learn to handle those students in a good way.

3. Recognition of how the students´ learning influenced their own ideas about teaching

In almost every portfolio the student teachers described how they had experienced situations in which they recognized the students´ learning abilities in a way that influenced their own ideas about teaching. In her portfolio Paula referred to a moment when she suddenly recognized that the learning of mathematics was everywhere in the child's world, and it was so important for her as a teacher to recognize that learning within the teaching practice:

> Paula: Today I sat with a two years old girl. She is often very quite and she loves to play with dolls. I sat next to her and I wanted to discuss some mathematics with her. But I got such a blackout so I just watched her playing. She sat there with her doll, and I could see how she fetched things for the doll. She fetched a blanket a perambulator and a bottle of milk. I saw so clearly that it was only *one* thing that she fetched. She did not fetch three or two, but one. This became clearer to me later when we had lunch. She was sitting at a table with two chairs. She put her doll on one chair and she put herself on another. I noticed that she had understood that it was two chairs because they were two for lunch. Later, when she had her meal she did the same thing, but this time she carefully shared her meal in two parts with the doll. It became so obvious for me…all the things that I have read in the books that mathematics

> is everywhere in the child's world. Before this moment I had thought that it was all about to make the children to count puppies, but now…yes now I understood that the mathematics was in the entire game. As for example when the girl fetched things to the doll or divided her meal into two parts. When I watched her playing I shivered because everything became so clear for me. It almost made me feel scary. During the whole week I had tried to have mathematics with the children, but as a matter of fact, the children gave to me what I was searching for. To see if small children were able to count and if they had a feeling for mathematics in different contexts. I came to see that it is not about using formulas or knowing all the concepts, but instead of how to use the mathematics and to benefit from it. That was the big secret that I came to see today. That little girl really taught me something good and unique, and it was to observe, to observe her world and to understand her mathematics. Of course I have observed children before in pre-school but then I only saw what I wanted to see. This time I did not have any expectations at all, and this time I saw for real!

Ellen recognized how the students 7 years old learned from explaining to each other. She stressed that it could be frustrating to explain something that is obvious for you, but that she learnt a lot while explaining and teaching. Hence, the students might also learn a lot when they explain to each other. Therefore she stressed the need her to know how to encourage the students to explain to each other and help each other if things are difficult.

> Ellen: One thing that I came to see today was how the students were helping each other. It is so fascinating to listen to how they explain to each other about how to do and why they do it. They are so very smart and I am impressed.

In Linda's portfolio she recognized how she and/or the teachers in pre-school could promote students´ learning of science. She referred to a moment when the pre-school teacher had the possibility to discuss science with the children but that she did not grasp the moment:

> Linda: Today one of the teachers missed the chance to discuss science with the children. We were outside and the teacher played with some children of 5-6 years old in a big heap of leaves just next to compost. When they stood there the teacher pointed at the compote and asked the children if any one of them knew what it was and why they had one like that at the schoolyard. One of the children answered compost but no one knew why it was there. The teacher asked what happened with all the leaves and the grass after a time and one child shouted that it became earth worms. The teacher then answered "Yes and soil…" And then she just left the children there standing in the heap. She had managed to make five very playful children to stop up and to reflect on why composts are important, she had a perfect chance to start to talk about circulation… and she just walked away!

Johanna referred to her discussion with two 4 years old girls and how easy it was to discuss quite difficult phenomena with the students. She recognized the need to grasp situations as they come up, to interpret the students´ reasoning, to build further on the students´ ideas and to stimulate their discussions:

> Johanna: Today I sat outside with two girls four years old and we were looking at the leaves. I told them that it was strange that the leaves on the trees were green but the leaves on the ground were brown. Jane told me that the brown leaves were old and when it is windy they all fall down and it is not that windy during the summers. This made us come into a discussion about why it was warmer in the summer than in the winter even if the sun is shining during both summer and winter, what is snow and from where comes the ice. Jane answered me that ice is dried water and it has dried because the clouds are drying when the sky is blue. When we sat there and philosophised I thought that perhaps this was my chance to ask her about

> what happened with the rain that that fell to the ground. The other girl, Annie, explained for me that the rain dries up because the sun is shining. Then we continued our discussion about why rain is good for the plants.

In summary almost all student teachers stressed that when discussing with the students during their practice they had come to see the importance of catching the small situations with the young students. They learnt a lot about students´ ideas and thoughts while discussing with them.

Discussion and conclusions - Learning to teach from teaching

As Shulman (1986) maintained, teachers need knowledge about the subject they teach but also about pedagogy and about children and how they best learn. Earlier research (Nilsson, in press) has showed that student teachers often focus on their teaching methods. Therefore the first main category was in some way expected. However, the other two (recognition of elements of knowledge needed for conflicts with students as well as between students; and the recognition and identification of the students´ learning in a way that influenced their own ideas about teaching) were more unexpected. This touches the very heart of the question of what does it really mean to acquire PCK and if it is possible to teach it to student teachers during their teacher education? In what way do primary teacher education curricula integrate aspects such as special need education knowledge, students´ learning and the complexity of learning to teach science into courses of subject matter and pedagogy? However, for learning to teach a crucial issue has proved to be the experience of teaching in the classroom. "The learning of student teachers is only meaningful and powerful when it is embedded in the experience of learning to teach. As teacher educators we need to be actively creating situations were this can occur and for it to be a natural part of teacher preparation" (Korthagen et al., 2006, p. 1030). Thus, to recognize and to further understand important elements needed for teaching while actually teaching might then be a precondition for their learning to teach.

As they struggle to teach maths and science in ways that make it meaningful to the young students, they draw on their growing of classroom management, of subject matter knowledge, of context, of students and of the curriculum. In short, they develop a new understanding of the knowledge of teaching, knowledge that Shulman (1986) has termed pedagogical content knowledge. The student teachers "stories" 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 aim of this paper was to discuss perspectives connected to the "knowledgebase needed for teaching" (i.e. PCK) and further explore how elements of knowledge are to be recognized within student teachers´ practice. In their portfolios the student teachers´ provided examples of situations within their teaching practice that they considered as important for their own learning to teach maths and science in pre- and primary schools. Using the ideas of Bishop & Denley (2007) (the spinning top) and Magnusson et al. (1999) it is reasonable to suggest that science PCK is a form of teacher knowledge transformed from other forms of teacher knowledge and is developed through the teacher's own experiences and science teaching practices. However, this paper indicates the importance of engaging science teachers in projects with a substantive focus of reflection of their own teaching of science in order to initiate the development of PCK. As highlighted by Korthagen et al. (2006), teaching as telling must be replaced by a way of teaching that implies a view of knowledge created by the learners themselves. In terms of teacher education, it is also important to be reminded that PCK constitutes more than the sum of its parts (Magnusson et al., 1999), so teaching and program structure need to be responsive to this point. Dewey (1916/1966) argued that teachers needed to see themselves as more than classroom "technicians" and move beyond

the goal of "technical rationality" towards being a "reflective teachers". Even if Dewey never used the concept of PCK it might be suggested that Dewey would have considered PCK as a reasonable way to show that teaching is so much more than technical skills. Stimulating student teachers' reflections on their own classroom experiences might influence their understanding of the complex relationship between their teaching, subject matter knowledge and the context to foster possibilities for the development of PCK.

To develop high quality science teaching in pre- and primary schools and for teacher preparation to serve an important role in that process, student teachers need to be encouraged to interpret teaching situations and recognize their knowledge needs. The results of this study highlight the importance of listening to student teachers' personal stories (e.g. through reflective portfolios) to consider the difficulties that they face within the teaching process. This is surely a fundamental basis for quality in teacher preparation and illustrates what it really means to develop a knowledgebase for teaching.

Implications for teacher education

What is then the value of a theoretical framework such as PCK in Swedish teacher education? As teacher education program must be targeted at student teachers' needs to translate required knowledge into effective classroom practice, the required knowledge and how it is developed must be further investigated. 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 to help 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. The PCK framework can be used in teacher education to design pedagogical strategies as well as an analytic lens to study changes in teacher educators' knowledge about "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 knowledges such as subject matter, pedagogy and knowledge of the context. Hence the PCK framework might help us to identify what is important and what is not in any discussions of teacher knowledge. Therefore, further research is crucial on how student teachers experience the practice of teaching, what constitutes teacher knowledge and in what way this knowledge impacts on students´ interest.

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