Chapter 8
Developing and Assessing Professional Knowledge as a Science Teacher Educator: Learning About Teaching from Student Teachers

Pernilla Nilsson and John Loughran

Self-study reports demonstrate that teacher educators can develop richer understandings of the complexities of teaching and learning, both for themselves and for their student teachers, through careful analysis of practice. Generally, the self-study literature tends to illustrate that learning about teacher education practices has focused more on programs and individual's practice (e.g., Berry, 2007; Brandenburg, 2008; Darling-Farr, Clarke, & Erickson, 2007; Samaras, 2006) and less on the particularities of the content being taught. Only recently have collections of self-studies of defined subject areas within teacher education emerged in the literature (e.g., Crowe, 2010; Schuck & Pereira, 2011). When teacher educators actively develop, assess and articulate the questions, problems, tensions and dilemmas in their practice within a specific subject area (e.g., teaching about the teaching of social studies, mathematics or science), specialized knowledge of that practice emerges. Such studies are important as they demonstrate the development of knowledge of practice within a specific content domain and offer new insights into teacher education practices.

Cochran-Smith and Zeichner (2005) called for more scientific research on teacher education – particularly in relation to how such studies could influence teacher education practices. As such, self-study research (Hamilton, Pinnegar, Russell, Loughran, & LaBoskey, 1998; Tidwell, Heston, & Fitzgerald, 2009) offers one way of responding to that call by facilitating the development and dissemination of learning from researching teacher educators' practice. Self-study research offers a

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P. Nilsson (✉)
Department of Teacher Education, Halmstad University, Halmstad, Sweden
e-mail: pernilla.nilsson@hh.se

J. Loughran
Faculty of Education, Monash University, Melbourne, VIC, Australia
e-mail: john.loughran@monash.edu

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powerful way of making explicit what one does and why, thus opening up to scrutiny the relationship between knowing and doing in teaching about teaching (Loughran & Berry, 2005).

Baird (2004) was of the view that teacher educators who begin by investigating their students' understandings of aspects of their teacher education program may learn something about the nature of their own actions as teacher educators and therefore gain new insights into the unintended effects of these actions. Wilcox, Watson, and Paterson (2004) drew attention to the fact that teacher educators' personal and professional learning is supported by their reflection on moments of disruption in their practice. The ability to reframe situations (Schön, 1983) and to actively seek out the disruptions and dilemmas that can make learning from researching practice uncomfortable is central to self-study. Berry (2004) captured the essence of this point when she stated that

> By researching their own practice, teacher educators ask themselves about the problems of teacher education and question how their own actions contribute to these problems. Developing a better understanding of the relationship between what teacher educators say and do is an important first step towards addressing such issues in their own work. In this way, the development of knowledge of teaching about teaching becomes both a personal quest, supporting the development of the teacher educator as an individual, and a professional responsibility, supporting the development of teacher education as a profession. (p. 1304)

Self-studies can pave the way for meaningful professional learning because they are embedded in teacher educators' real concerns and dilemmas within their practice. Pinnegar and Hamilton (2009) suggested that to understand practice more deeply, there is a need to use the voices of others in the practice setting to support the interpretations being made in that setting; there is a need to 'provide evidence of our claims about what our practice produces through their [students'] assignments, reflections, interviews, or actions in our practice' (p. 15). Therefore, drawing on the experiences of others is important, not just as a valuable source of data and analysis (Pinnegar & Hamilton) but also as a way of gaining alternative perceptions on situations under examination.

Unpacking teaching and learning to teach from the point of view of student teachers' experiences offers real ways for developing deeper understandings of their needs and their concerns (Nilsson, 2008). By using such experiences as data for investigating one's own practice, a self-study methodology allows that which may not have been seen, realized or understood in the practice setting to become more visible for teacher educators. Publishing such research then helps to share that learning with others and in the case of this chapter (and this book), does so in the context of teaching about science teaching.

Research Design and Context

As Baird (2004) so clearly explained, a self-study practitioner seeks, through reflection, a deeper understanding of context, practice and the interaction between the two. Through investigating her student teachers' understanding of their professional learning (specifically in relation to pedagogical content knowledge) over time, emphasis on the nature of her own actions as a teacher educator and the effects of those actions on her student teachers becomes central to the study.

The data at the heart of the self-study that is reported in this chapter is based on what became known as the science education CoRe project (Nilsson & Loughran, 2011) that was designed to explore the development of student teachers' pedagogical content knowledge in the teaching of science. This chapter is then built around the question: 'What can a teacher educator learn through analysing her student teachers' teaching and learning experiences and how does that learning influence her teaching about science teaching?'. As such, this self-study explores the learning that emerged when the first author analysed her student teachers' learning about science teaching through the lens of their self-assessments of their developing pedagogical content knowledge (PCK; see Shulman, 1986, 1987) as captured through their use of content representations (CoRes; see Loughran, Berry, & Mulhall, 2006).

Pedagogical Content Knowledge

When Shulman first introduced the construct of pedagogical content knowledge, it captured the attention of researchers because it carried the allure of being a specialized form of knowledge of practice. He described it as 'the blending of content and pedagogy into an understanding of how particular topics, problems or issues are organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction' (Shulman, 1987, p. 8). Since that time, PCK has been interpreted and researched in many different ways, but it has always maintained a place in the academic literature as an idea that has attracted considerable attention and consistently been revisited. For example, studies have been conducted to compare and contrast individual teachers' perceived PCK (e.g., Magnusson & Krajcik, 1993), the PCK of teachers as a group (e.g., Clermont, Borko, & Krajcik, 1994), as well as very specific studies based on particular content and topics (e.g., Parker & Heywood, 2000). Gess-Newsome and Lederman (1999) offered a compelling overview of PCK that has been influential in the work of many, but, generally, PCK research tended to focus mostly on the work of practising teachers. However, in recent times, student teachers' learning about PCK has become increasingly apparent as a field of research (Nilsson, 2008; Woolnough, 2009), and with efforts to make PCK more explicit through the work on CoRes and PaP-eRs (Loughran, Mulhall, & Berry, 2004), new ways of understanding the development of student teachers' learning about science teaching and learning have emerged.

Briefly, a content representation (CoRe) is a detailed description for teaching a concept whereby the 'big ideas' for the teaching of that concept are explored and developed through specific pedagogic prompts: What do you intend students to learn about this idea? Why is it important for students to know this? What else do you know about this idea that you do not intend students to know yet? Difficulties and limitations with teaching this idea, knowledge about students' thinking that influences your teaching of this idea, other factors that influence your teaching of this idea, teaching procedures and particular reasons for using them and specific ways of ascertaining students' understanding (for a full description, see Loughran et al., 2006). As such, working with a CoRe can help science student teachers conceptualize their professional learning and empower them to actively develop their professional knowledge of practice in specific content (i.e. offer glimpses into their developing PCK).

This chapter reports data from a program in which the semester begins with the student teachers being introduced to the CoRe approach. They then chose a specific science topic (chemistry or physics) to teach, both in the Science Learning Centre (SLC) at the university (in the middle of the semester) and during their 6-week school practicum (at the end of the semester). All student teachers (individually) complete an initial CoRe before teaching in the SLC (CoRe pretest). The CoRe acted as a prompt for student teachers to think about such things as that which they consider to be the 'big ideas' associated with teaching their topic based on their experiences, their knowledge of the content and of students' understandings, the teaching procedures (and particular reasons for using these) and their specific ways of ascertaining students' understanding or confusion around these ideas.

After their teaching experiences (which comprised that of the SLC, and their school practicum experience), all student teachers (individually) completed the CoRe for a second time (CoRe post-test). Following the CoRe, post-test participants compared and contrasted their two CoRes to determine how their thinking had changed and why. Through this reflection on their developing understanding of their teaching of science through CoRe construction, a formative assessment of their developing PCK was possible from both the pre- and post-test CoRe completions and the subsequent personal reflections on possible reasons for change from the participants' perspective. (There were other aspects to the CoRe project including self-assessments of level of confidence, perceived value, and understanding associated with CoRe completion on a scale of 1–10, as well as focus group interviews. However, data reported here is limited to that noted above because of the scope of the chapter.)

A teacher educator using such data through self-study methodology is able to learn about and develop their practice in meaningful ways because she or he is better informed about student teachers' issues and difficulties in learning to teach science. As such, student teachers' reflections on their approaches to teaching specific content offer feedback on their teaching and learning experiences in their teacher education program. Hence, the CoRe was experienced by the student teachers as a holistic tool to provoke their thinking about that which was important and why in the teaching of their chosen science topic.

The project was conducted within a primary science teacher education program in which student teachers ($n = 33$) used CoRes (Content Representation) as a tool to unpack their approach to the teaching of a science topic and the reasons for that approach. As such, the CoRe (Loughran et al., 2006, 2004) was used as a way of capturing the complexity and diversity of student teachers' PCK as well as to explore the questions, problems, tensions and dilemmas they experienced in their science teaching practice.

Beyond the data sources noted above, a critical friend (second author) was also employed in order to move beyond the individual practitioner and invite critique from another source. Methodologically, the use of a critical friend was important because 'working together and sharing ideas, issues and concerns with critical friends [can] help practitioners see beyond their own "world views" and broaden their perspective on situations in meaningful ways' (Loughran, 2004, p. 158). As such, a critical friend acts as a sounding board, asks challenging questions, supports reframing of events and joins in the professional learning experience (Schuck & Russell, 2005). Therefore, in this chapter, the critical friend played an important role in supporting and encouraging the teacher educator's self-study of practice through on-going conversations and e-mail contact designed to challenge and highlight discomforting situations that at an individual level may have been unattended or overlooked.

The results of the self-study (detailed in the next section of this chapter) are reported in the first author's voice as it is her experiences, her learning, and the development of her professional knowledge that is at the heart of this study. In essence, that learning is in response to two central questions:

1. What outcomes from the CoRe project informed my thinking about student teachers' learning about science teaching?
2. In what ways did these insights influence my conceptualization of teaching about science teaching?

Data Analysis

As the method section of this chapter makes clear, the self-study at the heart of this research project emerged as a consequence of a serious focus on the learning from teaching about teaching science (through the lens of PCK) in a primary science teacher education program. As has been noted many times in the self-study literature, the essence of learning through self-study is encapsulated in the nature of the knowledge that is developed as a consequence of the research. In this study, the notion of assertions (see, e.g., Berry & Loughran, 2002; Loughran, 2006) has been used as a way of framing and explicating the learning through the research as a form of knowledge that might not only speak to and inform the authors' practice but also be identifiable, meaningful and useable for others in their practice.

The language of assertions should be such that they easily make sense to the reader; hence, the wording of each assertion has been carefully constructed in the hope that such meaning is clearly conveyed. To ensure that the assertions are fully understood as evidence-based, and therefore carry a significant level of trustworthiness (i.e. as described by Lincoln and Guba (1985), that they are worth paying attention to), each of the assertions is explained with the data embedded in the explanation. In that way, it is anticipated that each assertion will then clearly demonstrate that the teacher educator has reframed (Schön, 1983) the practice setting in such a way as to question the taken for granted of existing teaching about science teaching.

Assertion 1: Student Teachers Do Not Learn From What I Say; They Learn From What I Do

This assertion is based on a realization that was similarly noted by Russell (1997) as he came to see the importance of his teaching about teaching in new ways as a consequence of listening more carefully to his student teachers' experiences. As Russell came to see his practice anew, he developed the mantra 'How I teach IS the message' not only as a way of directing and informing his pedagogical practices but also as a way of guiding his student teachers' learning about teaching. As such, he was constantly reminded of that which most influenced teaching and learning in his classes. In a similar vein, the assertion that 'Student teachers do not learn from what I say, they learn from what I do' offers a salient reminder that the very nature of teaching is crucial in shaping student teachers' learning about teaching. It also means that a teacher educator who works in that way is actively pursuing pedagogical practices through which actions and intentions are more closely aligned.

In working with a CoRe, a major conceptual issue is that of formulating the big ideas for the science topic under consideration. Big ideas offer a different way of thinking about how to structure a science topic from the typical curriculum approach that tends to be based around 'chunks of content' or information laid out in a stepwise fashion. However, simply telling student teachers that big ideas are not 'chunks of content' does not equate with their understanding how to conceptualize them in the way intended. They need the experience of attempting to develop big ideas and to analyse their attempts before they can grasp the full extent of how to conceptualize a topic in that way.

Although it appears obvious that experience matters in learning, the default position in teaching is often that of telling students about a problem then supplying them with the solution. That tends to happen more often than allowing them to struggle with the situation in order to better understand how to resolve the situation on their own. Hence, telling and doing are not the same thing for a learner, even though it can often feel that way to the teacher. Sandy's experience of formulating her big ideas is a reminder of that very point:

Sandy: In my CoRe 1 I wrote as my Big Ideas that the students should learn about nitrogen and oxygen. But in my CoRe 2 I thought it was more important to learn that air is something and that it exists even if we cannot see the particles.

The student teachers' self-assessments of their CoRes provided insights into issues that they considered problematic in terms of framing science content that, as their teacher, I overlooked. This is an example of not questioning the taken for granted assumptions. The student teachers found the notion of a big idea challenging because they had not previously experienced thinking about a topic in that way. I had introduced the CoRe in a way that I thought was thorough and careful. However, even though I talked a lot about the notion of big ideas and gave several examples of big ideas in science for different topics, the student teachers still struggled with how to formulate them when constructing their first CoRe (CoRe 1).

In reviewing their learning, it became clear that the manner in which they were taught about big ideas had little impact. Actually, in retrospect, I am not so sure that I really understood the difference between a science big idea and sequential textbook information. 'Telling them' may have satisfied my need to get information across to them but it did not satisfy their learning needs. Helen illustrated that point well:

Helen: I think that doing the CoRe made me focus much more on what were the essential ideas in my teaching… yes, such as the Big Ideas and why they were big. As such it helped me to get to the heart of what is important for students to learn. The CoRe made me aware of aspects outside the actual teaching that I as a teacher am confronted with in my daily work. We get a lot of tips on how to reflect but I must say that the CoRe gives something like a whole picture of what I need to consider when I plan my lessons.

Helen illustrates a crucial aspect of learning about how to formulate science big ideas: Learning is embedded in reflection on experience, and teaching should create the invitation for learners to engage in such reflection. The student teachers' self-assessments were another reminder of the importance of creating experiences and situations for student teachers to facilitate deep reflection and to give them time and space to refine and reconsider their own personal approaches and/or perspectives:

Mary: To use the CoRe as a tool for planning… I have really understood the importance of taking the time and energy to reflect… because the questions are so important as a starting point for me to reconsider my own professional knowledge. The importance of a deeper and more structured reflection is something that I have learnt.

The CoRe data provided evidence of how my student teachers' personal assessments became an object for constructive discussion and how that promoted reflection on their beliefs, concerns and needs – all of which are essential for good learning. Hence, as became increasingly evident, their experiences of using a CoRe helped them to better understand their own development of PCK. In so doing, the complexity and diversity of their own learning helped them see how that influenced their thinking about their teaching of their students. In many ways, their learning about teaching mirrored those things that were apparent to me in my teaching with them:

Ann: I have noticed that a lot of students have difficulties seeing and understanding [science ideas] and that you need to explain, experiment and discuss this more carefully than I thought in the beginning. The things that seem to be easy and obvious for me can be very difficult for my students. This is really something I need to reflect on in the future. I experienced that the science content is quite easy for me and it might be difficult for me to understand that the students think that it is difficult. This is an important insight that I will bring to the future. I am aware that I need to reflect on this when I plan and conduct my lessons… I also see the importance of reflecting after the lesson on what I have experienced and what I can learn from my failures and successes.

The ways in which these student teachers assessed their development (through using the CoRes) and shared their reflective experiences reinforce the importance of learning being embedded in experience and that telling does not equate to teaching:

Fiona: It is not good to 'hurry' through the concepts and the lessons just because you want the students to learn as much as possible. This will only lead to you losing the students because it does not get interesting when they think that it is too difficult. Then the students might lose their confidence and also their interest. It is much better to be calm, clear and structured so that the students really learn what you intend them to learn, before you go further to the next step. You cannot start to build a house by building the roof.

Student teachers need opportunities and possibilities to recognize and reflect on their successes and failures in order to develop confidence in the authority of their own experience (Munby & Russell, 1994). As Munby and Russell explained, student teachers need opportunities to develop deeper understandings of their own behaviours and the ideas that shape their actions and to be supported in learning to trust their judgments about their learning from their own experiences. Developing confidence in the authority of their own experiences stands in stark contrast to mandated learning derived from the information presented through the authority of position. In essence, it does not matter so much what they are told to do, rather it matters how they are guided to reflect on their learning.

My student teachers' reflections on their teaching and learning experiences of using the CoRe, as a way of paying attention to their developing PCK, became a mirror for me to look again at my own practice. I began to more clearly see what I was (or was not) doing in my teaching and what I was 'telling' them to do when I thought I was creating learning about science teaching situations. This experience of learning about my practice by being more attentive to their learning made clear that it is not what I say, it is what I do that matters.

Assertion 2: A Teacher Educator's Pedagogical Purposes Do Not Automatically Translate into Student Teachers' Learning

As a science teacher educator, I have certain pedagogical purposes that underpin my teaching about science teaching such as to stimulate student teachers' development of content knowledge, PCK and self-confidence in teaching science; stimulate their engagement and motivation; and, further, challenge their thinking about science teaching and learning. I often contextualize my practice through my own teaching experiences and/or through an appropriate theoretical lens. My teaching is therefore based on the view that theory informs practice and gives meaning to our understandings of teaching and learning practices and that reflection on experience is one way of building professional knowledge. As a consequence, I know that in my teaching of science teaching, I often refer to my own experiences of teaching science in an effort to make my learning accessible to my the student teachers. I do not believe this kind of thinking is unusual in a teacher educator's practice: If I share my experiences with my student teachers, or link the practice to theory, then they might learn through that approach. However, their self-assessments continually illustrated that my pedagogical purposes were not always recognized by my student teachers and certainly did not necessarily translate into their learning about teaching in the ways I envisaged.

Working with the CoRes has helped me see what it takes for student teachers to begin to examine the complexities of teaching and learning in science. No matter how much I am able to share my experiences of confronting students' alternative conceptions in my practice, it does not substitute for when student teachers seek out students' alternative conceptions in their own practice. Even though I can tell my preservice teachers that students often have difficulty in understanding concepts such as air takes space or that heavy objects can actually float in water, it is not until they experience *their* students' confusions, questions and reasoning themselves that they actually grasp the pedagogic essence of those ideas. Student teachers learn more through reflection on their teaching experiences than they do through reflecting on my teaching with them. That is not to dismiss the value of my teaching, but rather to acknowledge that it is a starting point for their learning about the complexity of science teaching, rather than as an end unto itself:

Chris: I thought that I knew a lot about students' conceptions and ideas. But when we had the lesson I understood that students have much more ideas than I ever could think of. They have a lot of different preconceptions and I guess that this is so hard to learn about in theory. Because how would you ever be able to be 'lectured' about students' spontaneous ideas and questions? So actually, I realised during the semester that the more teaching experience I got the more I came to see that students have a lot of ideas that are hard to predict… that really opened my eyes to how complex teaching is and how hard it is to learn to teach. The more you know, the more you understand that you don't know.

Teaching science is more complicated than student teachers initially believe. They need to experience students' confusion with concepts in order to genuinely grasp how that occurs and what it feels like to have to resolve such situations – experience precedes understanding. My student teachers' self-assessments continually highlighted how they had to have an experience in order to put their learning into practice in relation to their teaching and their students' learning.

Student teachers rarely, if ever, put the lessons I learned from my experiences into their practice. For example, despite demonstrating time and time again that students' ideas (i.e. working from students' prior knowledge) are crucial to shaping science learning, it was not until student teachers experienced it themselves in practice that they really understood the importance of accessing the learner's prior knowledge. Student teachers learned to tune in to their students' thinking in different ways, and this change in their perception affected both the student teacher and their class:

Ellen: Today, in the end of the project, I realise that the students' influence on lessons do not always need to be misconceptions. Students often have a lot of good thoughts and you have to be aware of and stimulate these thoughts.

Ann: When we did the mind map and this little guy came up with the suggestion that oxygen is blue. I was a little bit shocked and I did not know how to handle that comment. I mean, I did not want to say to him that he was wrong because I knew that he must have thought of the pictures of the human body where the veins are blue and the arteries are red. But I was not at all prepared for this and then the next time I did my CoRe I was much more aware of the different ideas that can come up… no perhaps not the different ideas but instead the fact that it is very difficult to predict a lesson in a correct way.

The CoRe project helped me see the power of doing research on student teachers' experiences in order to understand the complex interplay between my teaching and their learning. I now see the need to carefully clarify my purpose and select experiences for my student teachers that challenge their thinking and stimulate their personal growth. My student teachers do not necessarily interpret the pedagogical purposes that underpin my actions as important in shaping their learning about their practice. I need to be more attentive to student teachers' ways of expressing their experiences. As the data (above) suggests, the notion of alternative conceptions was clearly a crucial cornerstone in better linking specific content knowledge and pedagogy appropriate to developing better understandings of that knowledge in action. However, that purpose was not realized. Rather, many of the student teachers initially simply overlooked alternative conceptions as an influence on learning or lacked the confidence necessary to seek out and address alternative conceptions in their practice. As a consequence, I realize that I need to better understand how to use what I know about students' alternative conceptions in order to support the growth of my student teachers.

For many beginning elementary science teachers, there is a considerable difference between being aware of alternative conceptions and attempting to bring them to the surface in their teaching. The latter is considerably more demanding. It became increasingly clear that my pedagogical purpose of trying to identify important difficulties or limitations to science teaching and learning were not always visible or successful in influencing my student teachers' learning:

Mary: I have now had several lessons about water and I now know what the students have difficulties with and what they feel is hard to believe. Now I know more, but in my CoRe 1 it was mostly guessing. On the question of students' conceptions and misconceptions I thought it was very difficult to complete my CoRe 1 as I did not have any idea of what to answer… Now I know a little bit more about what a child at the age of 8–9 years can understand or misunderstand. But I have also realised that you cannot generalise for all students, they are all different.

There is little doubt that creating opportunities for student teachers to experience complex teaching situations, reflect upon them and then move beyond their immediate needs and concerns involves thoughtful approaches to teaching about teaching. As a teacher educator, it is important to be mindful of the importance of finding ways for student teachers to identify with particular teaching situations so that they are more confident about taking risks and creating their own opportunities for complex teaching situations:

Alan: Before the school based practice I thought that I had several ideas about students' conceptions. But now I realize that I had a quite limited understanding of things that students might experience as difficult. I might have got some specific sporadic ideas during my teacher education but I must admit that it is not very multifaceted or definitive. So I don't even want to count it as an artificial experience that I could rely on. It could be compared with as if I know how to say yes and thank you in Japanese, it does not say that I know the Japanese language. But now after this semester with the CoRes and the teaching experiences I think that I have more to say and that is at least enough to be counted as an experience. I feel that I know more about these things and that I know some of the most common misconceptions connected to the Big Ideas even though I do not know their proportions… Before my school based practice I did not think about students' questions. But now I try to think of metaphors and explanations and also in particular to reflect on what the students might ask. When I had the lesson and heard all the students' hypotheses and questions I came to see that students have a lot more in their heads than we teachers can ever think of.

Assertion 3: It Is Easier to Justify Your Actions Than to Study Your Practice

Reflection in action has long been recognized as an integral aspect of learning about and refining practice (Dewey, 1933; LaBoskey, 1991; Schön, 1983; Zeichner & Liston, 1996). Like many teacher educators, I encourage my student teachers to reflect on the 'what, how and why' of their teaching so that they might begin to see into the complex nature of science teaching. As assertion 2 suggests, I believe that theory informs practice and gives richer meaning to understandings of teaching and learning. Such a view creates an interesting dilemma for me as it can easily become a 'taken for granted assumption' in my teaching and lead to a situation in which I justify my actions rather than reflect upon my practice. Underpinning this situation is the need to find a balance between meeting student teachers' learning about teaching needs and helping to push them beyond their needs in order to challenge their learning. Berry (2004) explored aspects of this issue through her notion of tensions. In so doing, she recognized the problematic nature of teaching about teaching and how important it is to see practice from different perspectives, i.e. to seek to reframe (Schön) situations, not just accept them at face value.

As the student teachers' reflections were mirrored back to me through their self-assessments, I could see how important it was for them to see that I have questions about my own practice such as why do I choose particular experiments for them to experience, what influences how I respond to their needs and concerns, and why is practice problematic? When I analysed my student teachers' self-assessments, it became evident that they often transferred directly (without questioning why) my activities into their own teaching. Although I could happily justify my actions with them, when I reflected rather than rationalized, I could see that they were mimicking my practice without grasping the fundamental pedagogical reasoning at the heart of informed decision making in practice:

Fiona: What I am very satisfied with in my CoRe 1 was the method part and what to do but actually I found it difficult to explain WHY I chose these methods. That is why it is important to have an aim and a purpose with everything that you do.

I have learnt that by paying more careful attention to reflecting on my practice rather than justifying my actions, the pedagogical reasoning underpinning my teaching of science stands out more for my student teachers. In so doing, it helps them question their own teaching and to recognize the problematic nature of practice in a positive way:

Julia: When I compared how I had graded the meaningfulness in CoRe 1 and 2 I see different things that I felt were easy before but that I now experience as more difficult… which teaching methods I will use is also something that I consider as being more difficult [now].

Ellen: The question of why I want them to learn is good because you cannot answer that it is included in the school curricula… no you need to think of why the science content is important for the students. And I think that it is easy to forget about that. Yes, we are perhaps too focussed on what we and what the curricula bring up and we don't always consider the relevance for the students…

I need to remind myself to not allow the assumptions that underpin what, how and why I teach to become an excuse for my behaviours. It is sometimes easier to explain away some approaches because of the good intentions underpinning them than to seriously question approaches to teaching and learning. The taken for granted can mask the reality of the situation. I have become much more sensitive to that possibility through reflecting on my students' self-assessments:

> Analysing my student teachers' self-assessments became an eye opener for me about how easy it is to stick to your habits without reflecting on how your activities actually impact on student teachers' learning about science teaching… I want my student teachers to connect theory to practice and to use different pedagogical theories to inform their practice. But on the other hand, in what way do pedagogical theories inform our practices as teacher educators? It is much easier to justify activities than to really reflect on practice… I do not always communicate the reason for the activities to my student teachers. In the student teachers' reflections I noticed that a lot of activities they do with the children are the same activities that I do with them… the way the CoRe project required my student teachers to reflect on their Big Ideas and why they chose their different activities has made me question my own practice and the activities I choose. (e-mail correspondence with critical friend, 27 December 2010)

Assertion 4: Engaging with Science Must Be Seen as More Than 'Activities That Work'

Student teachers have a natural tendency to want to accumulate as many teaching procedures as possible in order to keep their students busy in the classroom and to have at their disposal a good range of teaching activities. My experience is that they filter their experiences in my classes in such a way as to build up a bank of activities that are easily transferrable to their classroom practice. As a consequence, I recognize the personal struggle between my desire to be acknowledged and appreciated as a teacher who can give them what they ask for and making clear that the different teaching activities fit together in a holistic way and are underpinned by pedagogical purposes. Finding a balance between giving them 'tips and tricks' and stimulating them to be more responsible for developing deeper understandings of science teaching is an ongoing issue.

When I analysed the CoRe data, I came to see how my student teachers often highlighted that they were doing experiments because they wanted their students to experience science as fun. One of my intentions in teaching about doing experiments is to help them see reasons for doing experiments, yet as their CoRe data illustrated, many did experiments without any deeper reflection as to why. A lot answered the CoRe prompt of 'why is this important for students to learn?' with 'they must see science as something fun and exciting'. Fiona's response (below) is indicative of that type of thinking:

> Fiona: Here my Big ideas were different as I have changed my Big Idea in CoRe 2 to 'air takes space'. Now I realise that the Big Ideas in my CoRe 1 were a little bit unnecessary. I think that I should have explored these ideas further. I planned to use a vacuum pump but honestly I don't even know if I had a purpose with this activity. I only wanted to use it to make a 'fun experiment'… actually I don't know what I was thinking of here.

What becomes clear through the CoRe data, and why this assertion is so important for teaching about science teaching, is the need to find ways of helping student teachers see that enjoying an activity, being busy or entertained, is not the same as being engaged in learning. In my own teaching, I need to ensure that my student teachers see beyond science as fun activities or as Appleton (2002) described it – 'activities that work'. I need their learning to be a catalyst for developing more sophisticated thinking about science teaching and learning. However, if they only interpret my science teaching as an array of activities that work, then I need to find ways of making more explicit how the use of experiments matters for building conceptual thinking – both of science content and their science pedagogical content knowledge.

Over the years, I have developed a repertoire of successful teaching strategies and science activities that I know will engage student teachers in the classroom. From a student teacher's perspective, however, my practice might be interpreted as 'activities that work'. I now see a need to be much more sensitive to that as a shaping force for how I develop my practice with them so that they see beyond a superficial interpretation of my pedagogy that meets their needs, towards a pedagogy of teacher education that challenges their thinking about practice at a deeper level:

Sandy: Concerning my teaching methods I have chosen the same methods in my CoRe 1 and CoRe 2 as I felt that the students were excited and liked what we did in the SLC [Science Learning Centre].

The same perhaps applies to the relationship between developing their understanding of the science curricula and the notion of big ideas. In their self-assessments, only a few mentioned the school science curricula and how the notion of big ideas actually helped in terms of implementing the curriculum in a meaningful way in their practice (which further reinforces assertion 2). I felt disappointed with that outcome because we had worked a lot with the national science curricula and I thought that the student teachers would see stronger connections with big ideas and the nature of the curricula:

Andy: We had chosen sound as we had looked into an experimental book that consisted of several physics experiment. We did not have very much knowledge about the content so when we tried to formulate the Big Ideas we worked them out from the small amount of facts that we had read in the literature.

When we started out with the CoRe project, we anticipated growth in students' learning about science teaching, but for some, that growth led to a regression in their personal self-assessment scores. This result (from the difference between self-assessment scores from CoRe 1 to CoRe 2) is, however, somewhat paradoxical because a decrease in confidence scores does not equate with a decrease in confidence in practice. Rather, it illustrates how student teachers come to see complexity of practice in new ways.

Learning about teaching science, if it is to go beyond accumulating activities that work, requires risk taking, and student teachers need opportunities to take risks and to learn from their experiences in positive ways. The change in confidence scores therefore draws attention to the fact that taking risks and experiencing the discomfort of being less certain about what is [or might be] happening encourages student teachers to question more deeply the nature of teaching and learning in science. Furthermore, experiencing a sense of frustration is important if they are to see and feel pedagogical problems in ways that will support risk taking and lead them to act in different ways:

Ellen: Another thing is that through the self-assessment when I compared the two CoRes I came to see how I developed or did not develop and that I even felt less confident the more I taught… Children are different and the situations will always differ. They have a lot of questions and ideas and the more you communicate with them the more you learn. Especially I became aware of the fact that students know much more than we think and that teaching is very complex and a lot of things can happen.

I need to provide my student teachers with chances to take risks and to experience uncertainty in their teaching in order to see beyond an activity that works approach to science teaching and to seriously engage with teaching as being problematic. This change needs to begin with the ways in which I construct and conduct my practice with them.

Conclusion

This study illustrates how careful attention to student teachers' experiences, ideas, issues and concerns about learning to teach science can help a teacher educator explicate and articulate her knowledge of practice. In so doing, the research reported in this chapter adds to the literature on a pedagogy of teacher education that has been growing in importance over the last two decades (Crowe & Berry, 2007; Heaton & Lampert, 1993; Korthagen & Kessels, 1999; Ritter, 2007; Russell & Loughran, 2007). The four assertions outlined in this chapter offer strong reminders about important issues that influence teaching about science teaching. Although well explained in the literature, self-study is inevitably very personal. In conducting this self-study, I (Pernilla) have come to see a tension between my beliefs and my actions in a way that challenges me to work towards a balance between my desire to offer my student teachers important knowledge of primary science teaching (such as different teaching approaches that work) and helping to push them beyond their initial needs in order to challenge their learning. However, what also became clear through this self-study is that student teachers need activities to feel confident and better prepared for their teaching, but my role as a teacher educator is to construct experiences that lead to careful analysis of the use of these tools. This tension therefore continually shapes my practice in ways that have become clearer and more defined as a consequence of conducting this study.

The experience of developing my understanding of practice through the frame of assertions has helped me build further on the idea of purpose in my practice and has also helped me to better see myself as a science teacher educator struggling with dilemmas. Learning about teaching is problematic. Part of my role is to help student teachers in their journey from learner to teacher, which is a never-ending process of investigating and analysing their own learning in order to formulate their personal professional theories and to use these theories to guide future actions (Nilsson, 2008). The challenge for me as a teacher educator is to guide this journey in a way that helps them to recognize the problematic nature of teaching and learning about teaching and to see their practice from different perspectives. At the same time, structuring my learning through the notion of assertions offers me an interesting way of being reminded about the issues and concerns in teaching about teaching science. The assertions act as advance organizers in ways similar to that described by Ausubel (1960) and help me approach my practice in a way that is open and responsive to my student teachers' learning. Assertions help me to build opportunities for my student teachers to become more confident in learning from the authority of their experience. They thus help to stop me falling for the false sense of security that accompanies subconsciously operating through the authority of position, which can so easily happen when telling masquerades as teaching.

Through this self-study, my student teachers' experiences and dilemmas became a mirror for me in terms of seeing the same in my own teaching about science teaching, reminding me again of the ideas of Bishop and Denley (2007) who stated 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). Reframing my practice through self-study has produced better insight into the complex process of becoming a science teacher and what I as a teacher educator can do to support that process:

> I think it is interesting to [have done this] self-study because even though you do research on your student teachers' learning, that which you, as a teacher educator, learn from your student teachers is not always evident. However, working with a critical friend pushing your ideas further by asking the right questions puts your ideas under the magnifying glass… I guess that as experienced teacher educators we have (at least most of the time) quite clear ideas of what and why we are doing things, but these ideas might be not be very well expressed or articulated for ourselves or for our student teachers. Doing a self-study forces you to break down your old habits, which can be quite painful and create a lot of work, but it is a true way of actually improving your practice as a science teacher educator. (e-mail correspondence with critical friend, 9 January 2011)

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