Constructivism Deconstructed in Science Teacher Education.

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Abstract: Constructivism posits that the teacher's role is to help their students to actively construct new understanding for themselves. Diagnosis of students' prior understanding followed by carefully planned teaching sequences enables learners to grasp hitherto unknown concepts. Assessing whether they can then apply their new knowledge in new contexts verifies whether or not they have learnt what the teacher has taught. Using these three steps (diagnose, engage, evaluate) to structure a self-study highlighted the gap between rhetoric and reality in a science education methods course. This self-study research - which draws on journal entries; students' and colleagues' perspectives generated through questionnaires and interviews; and critical friends critique and questioning - had a significant impact on my teacher education pedagogy.

Introduction

Teaching student teachers how to teach science in the primary classroom is no mean feat. Science is a complex and broad subject and the science education research literature is replete with students' (mis)conceptions and difficulties in learning science (e.g. Duit &Treagust, 2003; Osborne & Freyberg, 1985; Skamp, 2008). Developing student teachers' confidence with both science content and pedagogical knowledge specific to science is critical to them being willing and able to make science accessible, relevant and engaging for their learners. Teaching science effectively in primary schools is dependent upon understanding the complex relationship between learners' prior understanding, science content, teaching approaches, and pedagogical content knowledge. Pedagogical content knowledge (PCK) (Shulman, 1986) refers to a teacher's ability to integrate pedagogical knowledge, contextual knowledge and an understanding of subject content.

Prior to this self-study, I relied on my experience as a science teacher to model what was considered to be exemplary teaching practice based on a constructivist approach. I was the designated course coordinator and one of three teacher educators teaching in the course. In my sessions I demonstrated various ways to diagnose learners' prior understandings about a science topic and then modeled ways to orchestrate rich learning experiences that would challenge those learners to construct new understandings about a range of science concepts. I then gave my student teachers ways to evaluate whether learners had understood what had been taught. This was contextualized and prescribed by the new curriculum (Ministry of Education, 2007).

In a science education course with only 24 hours of contact time, I thought that we should model good practices that would enable student teachers to learn fundamental science content and experience a pedagogically-sound, practical-based approach. Prior to this research, there was only one assessment task for the course. This was a micro-teaching assignment which was based on each student teacher following our example of how to diagnose, engage, and evaluate three or four children's understandings about a narrow, specified science topic. The narrow focus of the course assessment task meant that many had limited exposure to science content or teaching science. This was compounded by the fact that student teachers rarely saw science being taught (effectively or otherwise) when they were on practicum and so they had little opportunity to see a teacher who had well-developed pedagogical content knowledge in action. Furthermore, the realities of an overcrowded curriculum and lack of emphasis on science in New Zealand primary schools (Education Review Office, 2004; Schagen & Hipkins, 2008) meant that our message that science was an important subject was not reinforced by student teachers' practicum experiences.

Given these limitations, the aim of the course - to foster student teachers' confidence and competence to teach science effectively using a constructivist approach - was reduced to little more than a how-to-teach template. Demonstrating how science could be taught using this approach reinforced transmission of information and reduced constructivist underpinnings to a formulaic series of how to diagnose; engage; evaluate. In our haste to deliver subject specific content knowledge and model constructivist-based teaching approaches, we presented science teaching as unproblematic. In effect our teacher education pedagogy was based on 'do as we say, not as we do.'

We presumed that modeling teaching science would be sufficiently powerful to enable student teachers to follow our example in their classrooms. In this article I question whether modeling such a formulaic approach to building understanding about science content diminished the emphasis on engaging student teachers in learning about teaching science. Did I hide behind my subject specific knowledge because I lacked the confidence and expertise to challenge student teachers' understanding of teaching? Or was the constructivist approach that I suggested my students use when they were teaching science unworkable in a teacher education methods course?

This self study enabled me to revise what a constructivist approach to teaching through science, rather than science content, could look like in a science methods course.

Contextualizing Literature

Constructivism emphasises the importance of the knowledge, beliefs and skills that an individual brings to the experience of learning. In its many different forms (from a Piagetian notion of an individual's adaptation and assimilation of new information to an emphasis on learning as the product of complex socio-cultural processes, as suggested by Bruner, Lave, Rogoff, and Vygotsky), the learner is an active participant. As such, they are involved in the interpretation of meaning, the reflection of experience and the re-construction of the experience to become more knowing. The rise of interest in constructivism has made the practice of teaching increasingly complex for teachers. As Richardson (1997) wrote:

> We have a tendency to attempt to work out the complexities of our theories in the hallowed halls of academia and academic conferences. And then, quite cavalierly, we turn it over to the practitioners to work out the practices. 'Here's a neat idea,' we say, 'it's called constructivist teaching. You should be doing it in your classrooms.' We don't mention the theoretical disagreements, nor do we admit that turning a theory of learning into a theory of teaching is an inexact process, at best. (p. 12)

This was true in New Zealand where the educational theory which underpinned the science curriculum document (Ministry of Education, 1993) was based on the Learning in Science Project (Osborne & Freyberg, 1985). Rather than prescribing a mass of content knowledge to be taught, the emphasis was placed on learners making sense of their world and science in contexts that were of relevance to them. Teaching leant heavily on a personal constructivist view of learning. But the approach was not without its vocal opponents. Matthews (1995) was foremost in expressing his opinion that the science curriculum and constructivist view of learning devalued scientific knowledge and led to a watering down of science knowledge. He claimed that within the constructivist model "knowledge is degraded to whatever makes sense to you, or whatever suits your person or class interest" (p.125). The rhetoric of constructivism was misconstrued and taken as licence to claim that anything goes. This laissez faire approach was captured by a teacher education student who wrote: "Constructivism has taught me I do not need to know any science in order to teach it. I will simply allow my students to figure things out for themselves, for I know there is no right answer" (Korthagen & Lunenberg, 2004 p. 436).

But such minimal guidance has been shown to be "significantly less effective and efficient than guidance specifically designed to support the cognitive processing necessary for learning" (Kirchner, Sweller, Clark, 2006; p. 76). They refute that students are able to learn merely through exposure to information rich settings or through experiencing disciplinary procedures (e.g. working like a scientist to uncover science concepts). However, constructivism never espoused one particular technique for ensuring learning. Rather, it provided a way for teachers to look at and adapt teaching and learning activities to suit their situations (Trumbull, 1999). Teaching using a constructivist approach emphasises the role of pedagogical content knowledge and a teacher's ability to engage their learners in knowledge construction. The initial steps of diagnosing a learner's current ideas are the easiest to accomplish. As Harlen (2001) noted:

> The knowledge we now have of how to elicit children's ideas and what we are likely to find is not, unfortunately, matched by knowledge of how to help children towards more scientific ideas. Consequently "constructivist" teaching has often stopped short after collecting ideas and making some attempt to categorise them. A major problem is the uncertainty in the situation which seems to militate against planning. Until we know what children's ideas are, how can we plan to do

> something about them? The solution lies in being prepared and being flexible. (p. 16)

A number of studies (e.g. Appleton, 2008; Watters & Ginns, 2000) indicate that teachers often lack the rich subject matter knowledge required to be flexible and responsive to students' thinking and to foster learning with understanding. For example, Vlaardingerbroek and Neil Taylor (2003) noted that in some cases teachers were unable to identify incorrect conceptions in student responses because their own understanding was weak. For these teachers, "no problem with their pupils' understanding appears to exist" (p. 431).

The literature reviewed here clearly supports the view that for teachers to be successful teachers of science they need to know science content; they need to know about teaching and learning strategies; and they need to be able to combine science content knowledge and pedagogical knowledge into pedagogical content knowledge for teaching science. Teacher education science courses need to prepare beginning teachers who are capable of planning, delivering and evaluating science lessons and who are confident of their ability to teach science well. According to the literature (e.g. Appleton & Kindt, 2002; Harlen, 1997; Kelly, 2000; Preece, 2004; Sanders & Morris, 2000; Shallcross & Spink, 2002) the majority of student teachers entering teacher education programmes have limited science subject knowledge and negative attitudes towards teaching science. Having the confidence and ability to direct students' learning in a constructivist way depends on the teacher's own sense of confidence to manage the learning environment safely and competently and to be able to deal with observations and questions from students which are unexpected. Adopting an approach which may lead to greater understanding for learners but depends less on the transmission of facts is challenging for teachers inexperienced in more interactive approaches. Learning science requires the teacher do more than set up challenges and encourage students to work it out for themselves (Roth, Tobin, & Ritchie, 2001). Teachers who are insecure in their knowledge of science find the uncomplicated transmission of knowledge attractive and revert to more traditional teacher-directed methods when they are less confident (Appleton & Kindt, 2002).

Could the same be said of student teachers' experience of learning to teach science in this course? Were they expected to "work teaching out" without teacher educators challenging them to explore, extend, and reflect on their personal framework of understanding about teaching? This self-study explores the issues I encountered when adopting a constructivist approach to science teacher education.

Self-Study Method, Data Sources and Data Analysis

As with other forms of practitioner research, in self study, "the researcher inquires into problems situated in practice, engages in cycles of research, and systematically collects and analyzes data to improve practice" (Samaras & Freese, 2009, p. 5). Rather than changing teacher education practices as an action research project might, self-study focuses on the transformation brought about at a personal and professional level. The unique identifier of self-study is the focus on oneself and the understanding we bring to the research of ourselves as practitioners in the act of teaching. Maintaining this focus requires a disciplined and conscious effort. As Ham and Kane (2004) explain:

> Self-studiers are actively inviting the reader to see them, or their experience as they have investigated it, as 'a case' of something. This locating is a way of signposting where they see their study or experience fitting in terms of the more general body of public knowledge… It is the reflexive practitioner trying to be the reflexive researcher as well. It is the movement in stance from being the object of one's subjectivity to being the subject of one's own objectivity. (p.117)

Self-study leads to reconceptualising the role of the teacher educator (LaBoskey, 2004). It is a transparent and systematic research process in which multiple methods are used to generate and gather data. Importantly, self-study is a collaborative endeavour and, as such, research is shared with critical friends who question assumptions and provoke new perspectives throughout the project. In this case, critical friends were students in the course, colleagues teaching the course and other teacher educators within and external to the institution (Paugh & Robinson, 2009). As is required of research, it is made public for peer review and critique. Then the potential of quality self-study, beyond my own personal and professional development, is to contribute to the other teacher educators' professional knowledge.

Trustworthiness and credibility of interpretations were strengthened by using multiple and varied data sources (Samaras, 2011). One source of data in this self-study was comments and feedback from students and colleagues teaching in the course generated through three questionnaires and focus group interviews. The questionnaires were designed to gather self-reported perceptions about confidence and competence to teach science and feelings towards, and expectations of the course using Likert scales and open-ended questions at the beginning of the teacher education programme (February); at the start of the science course (July); and at the end of the programme (November). Items included: Rate your confidence in your subject knowledge of the following subjects; Rate your confidence to teach each of the following subjects; What are your expectations of the science education course? In the end of course questionnaire items included: How have you learnt the most important things in the science education methods course? What are they? The number of students enrolled in the program varied between 80 and 90 with response rates to the questionnaires consistently better than 80%.

I presented a preliminary analysis of the aggregated student data to all of the students. This served as a form of member checking. I also invited students to participate in informal focus group interviews to discuss my findings. Fifteen graduating students participated in these interviews at the conclusion of their teacher education programme.

I gathered the other teacher educators' perspectives on teaching in the science education methods course. I asked them (and myself) to complete modified questionnaires which I then discussed with them. I asked my colleagues to answer the questions for themselves (i.e. to rate their confidence to teach biology or physics) and also to speculate on how the student teachers responded. For example, I had asked the students how they had learnt the most important things in the science course and what they were, which I modified to be "What do you think the students are going to report were the most important things they learnt and how did they learn them?" I answered the questionnaire myself before I analysed the students' responses and before I interviewed my colleagues. Cross-checking and comparing perspectives of colleagues and students when gathering and writing up the data was a way of ensuring the trustworthiness of the study (Samaras, 2011)

A second source of data was my electronic journal entries. Using the guidelines outlined by Bolton (2005), I recorded my impressions and descriptions of discussions, conversations and reflections. Writing in my e-journal was an opportunity to not only capture descriptions of events and situations I encountered, but also to enrich and expand this data set as I reflected on and reconstructed what had taken place in my teaching sessions, conversations and interviews with students and colleagues and my responses to them. I annotated my journal with comments about my reactions to conversations, or similarities and differences I noted between perspectives, or reflections as I revisited the data. I shared key ideas, observations and thoughts in subsequent sessions with my students as a further form of member checking. In total there are 41 separate journal entries, ranging from 227 to 1,500 words, with an average number of 719 words.

My focus when analysing this collective and expanding data set was to make sense of the information as a teacher educator simultaneously immersed in teaching and researching that teaching. Data collection and data analysis did not happen linearly but was "an hermeneutic spiral of questioning, discovery, challenge, framing, reframing and revisiting" (Samaras, 2011, p.81). As I considered newly generated entries I recognised emergent themes. Many of these themes appeared interrelated. Searching for connections and patterns across them and sharing my interpretations in regular discussion with two other critical friends, became a further step in my analysis. The opportunity to articulate my developing understanding and respond to their critique enabled me to sense how my changing practice resonated with others. Such interactions allowed validation of experiences and ideas and were an opportunity for them to link my accounts with their own experiences (Loughran & Northfield, 1998) Finally, as recommended by Lankshear and Knobel (2004), I revisited the data to look for particular instances which supported or disconfirmed the themes which had emerged and considered my analysis in the wider context of the research literature.

In the discussion that follows I take each of the three aspects of constructivist teaching - diagnose, engage and evaluate - and consider (i), the student teachers' perceptions compared to the teacher educators' perceptions and (ii) how my pedagogy was challenged.

Discussion

Diagnose: Perceptions of Prior Experience, Confidence and Competence

Key to adopting a constructivist approach to teaching is for the teacher educator to know their learners' prior knowledge so that they can engage them in reconstructing personal frameworks of understanding. I diligently diagnosed my student teachers' understanding about science concepts but I knew little about their prior experiences or expectations of teaching science. I assumed, as indicated by the literature reviewed, that they would have limited science content knowledge and negative feelings towards teaching science in primary schools.

Student Teachers' Perceptions

Analysis of student teachers' responses in the first questionnaire (February, n=75) indicated that they were overwhelmingly positive about teaching all subjects at primary level, regardless of their own school background, their confidence in their subject knowledge and/or their confidence in their ability to teach the subjects. Less than 3% of students felt negatively towards teaching science. Their comments were typified by the following example:

> I feel positive [about] teaching most subject areas. Although I have a lot to learn about teaching – I feel confident that my ability in the subject areas is still greater than primary-aged children (Student comment; First questionnaire).

Science was ranked fifth of seven subjects for student teachers' perceived confidence and ability, although around two out of every three students thought that their subject content and their ability to teach science was strong. However, when student teachers were asked to rank their perceptions in each of the sciences (biology, physics, chemistry, geology and astronomy) in the second questionnaire (July, n=78), their perception of confidence, competence and ability was significantly higher in biology than the other sciences, a trend noted by Harlen (1997). Student teachers also reported that they were positive about learning science and that they were eager to participate in "practical sessions".

Teacher Educators' Perceptions

The student teachers' confidence in their subject knowledge and ability to teach that content to others came as a surprise to us. It was contrary to our belief that they would have limited knowledge and be lacking in confidence. We countered their attitude of 'How difficult can it be?' with a dismissive 'How little they know!' Initially, it remained our contention that improving science content knowledge would better equip them to teach science effectively in their classrooms. Our underlying assumption, based on our collective experiences and a critical reading of the literature, was that science was particularly difficult to teach well with limited background knowledge and, therefore, it was likely to be a subject student teachers would avoid teaching.

In my journal I reflected on my own and the other teacher educators' comments about our prior experience, confidence, and competence towards teaching each of the science subjects. Two of us had majored in Biology and had previous experience as secondary school teachers. We both considered our science subject knowledge to be our strength. I considered Biology to be my forte but the other teacher educator thought that it was more difficult to teach biology than other science subjects because she was too well aware of its complexity. She commented:

> I think I teach biology not as well as chemistry and physics because the anomalies are much more apparent. I think that when you're first starting [teaching] it's better to have a clearer idea of where you are going, even if it's a bit simplistic. I think that I teach [physics] pragmatically, and I teach the essence of it. In biology, I often don't

> know where to start with the evolution topic because you sort of know too much. (Interview: December 2004)

We were confident of our membership of the community of practice that might be labeled 'the biology/science teachers' community' (Wenger, 1998). However, since neither of us had taught in a primary classroom, we both felt less confident of our place in the primary teachers' community and we frequently reverted to traditional teacher-directed methods. This sense of inadequacy was sufficiently strong for my colleague to choose to combine classes with the other teacher educator because she had 15 years experience of teaching in primary classrooms. In her interview, the third teacher educator claimed strengths and confidence in teaching all of the areas of science covered in the course on the basis of 15 years of experience and having taken biology and chemistry to high school level.

Engage: Expectations of the Science Education Course

The course was originally designed in such a way that the onus was on the lecturers to provide a balance of educational concepts that underpinned best practice and an understanding of science concepts. This was accepted as the norm by the student teachers and the lecturers.

Student Teachers' Expectations

At the start of the course (July), 62 out of 78 student teachers' responded to open-ended questions probing their goals and expectations of the science education course with statements about improving their content knowledge in science. For example:

> I need basic science concepts and facts in my knowledge bank. (Student teacher comment: July questionnaire)

More than half of them expected that they would receive resources and useful activities, and more than a third expected that science would be made fun for them. Their comments included:

> I want to be given ideas and resources that can be used when working with children.
> To be taught what is the most essential knowledge to get through a couple of units.
> To have some fun and learn how to make the subject fun and exciting for children. (Student teachers' comments: July questionnaire)

The majority of student teachers were focused on the importance of content knowledge to enhance their sense of self-efficacy. At the outset of the science education course they appeared enthusiastic and eager to engage as learners of science content rather than as students of science teaching. They anticipated that their lecturers would model good pedagogy and demonstrate exemplary practice that they could then copy.

Teacher Educators' Expectations

We take pride in our consistently high ratings in student teachers' evaluations across factors such as being organised, well-prepared and knowledgeable. Student teachers' evaluations are used in our annual performance appraisals and their comments encourage us to conform to modelling enthusiasm and pedagogical content knowledge. Through the course content and our actions, we expected to engender confidence and competence. One teacher educator commented:

> I think a lot of them should say [I feel more enthusiastic about teaching science than most other subjects] because they certainly expressed that they found science more interesting than a lot of the other subjects – especially what do they call them, the 'blah-blah' ones like Education and Professional Inquiry where they just sat and had it given to them rather than participating and doing some peer-teaching. (Interview: December 2004)

I reflected that my confidence and enjoyment was based on my ability to teach science content in engaging ways. I relished the role of expert science teacher and sage on the stage, as highlighted by a comment in my journal:

> I said to them at 11.20, yikes, I really wanted to teach this about the development of the vertebrates. I said I love teaching this and if we had more time I would spend a couple of sessions showing off to you about how much I know! They laughed but I realise that it is true, I do want to show off how much I know and impress them. (Journal entry: 20 August 2004)

Teacher educators can find themselves unsupported by their colleagues and the students they teach when they try to adopt new roles. Challenging the status quo can lead to uncertainty and confusion for both parties. When I read the reasons why Myers (2002) thought that telling, showing and guided practice might be standard practice in many teacher education programmes his second point, in particular, was most apt.

> Many teacher educators are not secure and courageous enough to question what they do, to experiment. They choose to view teaching as doing what they do "the right way", rather than a continuous process of experimentation, reflection, analysis and learning from experience. They seem to think that teaching in ways that are not 'the right way' is, in effect, poor teaching. They cannot risk being thought of as poor teachers. (p.137)

There is a tendency for us to protect our status as experts of science teaching rather than explore alternative approaches to being teacher educators. I was increasingly mindful that modeling how to teach science was not engaging student teachers in learning about teaching science in a meaningful way. With this in mind, I formally scheduled peer-teaching as an integral component of the science education course. We set aside up to 30 minutes in each of four sessions for one student teacher per group to teach a science idea to three or four of their peers. Peer teaching afforded student teachers the opportunity to engage meaningfully and authentically in situations that promoted deliberate practice. They were responsible for sourcing information and activities and were encouraged to adopt the role of teacher, albeit for 30 minutes. However, they were also required to give one another feedback about their teaching when they were 'students'. In this way each student gave and received critique from their peers about strengths and weakness in their teaching. It is beyond the scope of this paper to discuss peer-teaching in detail (see Garbett & Ovens, 2010; Ovens & Garbett, 2008) but the results impacted on our teacher education pedagogy and featured prominently in the comments of student teachers and teacher educators in their final evaluation of the course.

Evaluation of the Course
Student Teachers' Evaluation

In the end of course evaluation (November, n=91) student teachers were asked to rate their perceived confidence and competence to teach science. Three out of four student teachers felt more confident to teach science than most other subjects and two out of three student teachers agreed with the statement that they were more enthusiastic about teaching science than most other subjects. Another trend was that student teachers became less concerned that they needed to know a lot of science content in order to teach it well.

Student teachers were asked to answer an open-ended question about the most important aspects of science they had learnt. Science content was still considered very important for half of the student teachers but it was not the most frequently cited aspect. As I read their other comments in their final evaluation (for example: Children have misconceptions about science but these can be utilised in the teaching process) it was apparent that *teaching* science was the most important aspect for the student teachers. The practicalities of teaching science were mentioned by three out of four student teachers. For example:

> A range of hands-on activities/experiments I can use in my classroom programme.
> How to access and <u>use</u> resources in my classroom. (Student teachers' comments: November questionnaire)

Nearly all of the student teachers responded positively to the question 'Has peer teaching been a successful component of this course?' claiming that it was valuable and beneficial to have first-hand teaching experience (for example: Peer teaching was great; Great to have teaching and learning roles within the course (i.e. having experiences of both). The science education course, and the changed pedagogy practiced in it (i.e. the introduction of peer teaching) gave student teachers the opportunity to feel confident in their ability to diagnose their learners' prior science knowledge, source appropriate information and make it accessible through engaging learning experiences.

Teacher Educators' Evaluation of the Most Important Aspects of Science Learnt

I compared the student teachers' answers to what we thought we had taught, what we thought we had assessed, and what we thought the students' had learnt. We all stated that science content knowledge was the most important thing we had taught, what we had assessed the students on, and what they had learnt from us. We also included skills - such as the ability to plan a lesson or unit, to select appropriate teaching strategies, to diagnose prior knowledge (children's and their own) and to make use of resources. We remained focused on teaching them how to teach science through modeling and providing exemplary practice. Repeating information that we had given them or that they had read in reference material was generally considered acceptable. As one teacher educator commented:

> We assessed their ability to either generate or replicate activities in science. I told them I didn't [generate new material] when I was out there teaching – that's why they publish [teacher resources]. What's wrong with regurgitation when it comes to activities? If the activities match the concept, let's face it, many of us can write a unit plan but we don't make up new stuff… You haven't got time. (Interview: December 2004)

Another talked at length about how she had learned to teach science by standing in a backroom listening to a more experienced teacher teaching. For her, modeling was the most effective way of teaching. She said:

> The most effective form of teaching is to model what you want your outcome [to be]. The most effective form of learning you get is actually watching other people do what you want. I copied him because I didn't know anything and sometimes the copy worked and sometimes it didn't. (Interview: December 2004)

She went on to comment:

> We assess students on their ability to interpret children's ideas. I don't think they get the next bit – you know – they won't get the bit about what you do about it…They don't actually think about the next stage. I mean that's what we wanted them to do but I think that a lot of them just say OK, you've got this misconception now this is the answer and they sort of told them. They didn't explore that. (Interview: December 2004)

As I reflected on these comments in my journal I realised that engaging student teachers in learning about teaching was not a skill that we had mastered. Nor was students' understanding of teaching science something we evaluated. It was easier to evaluate *what* we had taught in terms of subject matter content or lesson planning techniques than it was to evaluate *why* we considered these to be important to teaching science.

My evaluation of myself as a teacher educator amounted to the realization that neither subject matter knowledge nor practical experience of teaching in a classroom was adequate guarantee of my being confident or competent as a teacher educator. It took this self-study for me to realise that I had a great deal to learn about teacher education, even with 20 years of experience.

Concluding Thoughts

I am not suggesting that all of the difficulties of teaching science in primary schools can be addressed through implementing a change such as peer-teaching in teacher education pedagogy. However, I am convinced that modeling exemplary practice is inadequate preparation for student teachers. Giving them the opportunity to teach their peers opened my eyes to the fact that there was a lot more learning taking place that I was not responsible for and could not instigate by maintaining the authoritative mantle of expert science teacher. By stepping aside from the science teacher's role to ensure that the student teachers experienced teaching science for themselves I created avenues for the student teachers to participate in a community of practice that had its focus on science teaching rather than science learning. It enabled them to practise a constructivist approach to teaching which we had modelled - of being knowledgeable guides who were prepared to listen to their learners and to develop their understanding through presenting stimulating ideas and activities, questioning and explaining and redirecting the learning towards more scientifically accepted ideas.

This self-study research gave me the opportunity to develop a similar approach to teach about teaching. I became a more knowledgeable guide, prepared to listen to my learners. I heard their perceptions of what knowledge they needed to be effective teachers of science in primary schools and compared that with my own and my colleagues' perceptions. I believe that the implications of this self-study for teacher education pedagogy extend beyond the curriculum area of science in primary schools into other curriculum areas as well as into early childhood and secondary teacher education.

The students developed their understanding of learning to teach through being positioned in authentic and enagaging teaching situations. They were challenged to reflect on their personal framework of understanding about teaching. In studying what a constructivist approach to teaching might look like I explored what I was doing, why I was doing it and how I communicated that through my practice (Loughran, 2006). I, too, was challenged to reflect on my understanding of what it was to be a teacher of teachers.

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