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In-service teachers' perspectives of pre-service teachers' knowledge domains in science

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The concept of pedagogical content knowledge is integral to teaching as a profession and is often considered to be an important aspect of a teacher's lived experience. Pedagogical content knowledge (PCK) is described as a transformation of teacher knowledge from a variety of domains of knowledge, which includes subject matter knowledge, pedagogical knowledge, and knowledge about content. This exploratory study reports on in-service natural science teachers' inferences regarding pre-service teachers' performance in natural science teaching, as observed during a practice teaching period. Perspectives of in-service teachers of the different knowledge domains of pre-service teachers during their final year were investigated. Semi-structured interviews, incorporating a specific set of open-ended questions, were conducted with in-service teachers following a practice teaching period of four weeks. The findings indicate that the in-service teachers rated the pre-service teachers positively in some knowledge domains but less positively in other knowledge domains. This has prompted some rethinking on the structure and presentation of the curriculum, in our undergraduate teacher education programme, to include and accommodate approaches that would enable better uptake of various knowledge domains and improve PCK development.

Keywords: in-service teachers; pedagogical content knowledge; pre-service teachers; teacher knowledge

Introduction

In order to improve professional development in pre-service teachers (teachers in training), in particular, learning communities need to be established between schools and tertiary education institutions, between experienced mentor teachers (in-service teachers) and pre-service teachers as well as between teacher educators and in-service teachers (Agbo, 2003). Agbo (2003) argues that collaboration within professional development communities and learning communities alike could be seen as "learning about teaching and teaching about learning". This learning from one another could only be possible when one of the parties/participants is an experienced teacher/mentor or teacher educator. This symbiotic collaboration also provides solutions for concurrent effective teacher education and therefore the improvement of the preparation of pre-service teachers (Agbo, 2003). Aitken and Mildon (1992) are of the opinion that pre-service teachers "need to talk to more experienced teachers" on their way to becoming qualified teachers. There is a need for experienced mentors at the schools where pre-service teachers do their practical training (Aitken & Mildon, 1992:33).

According to Sikes (1992:45), the older teachers have longer-term perspectives on teaching and learning, since they "have seen it all before". It is therefore also true that experiences in science teaching, accompanied by acquired knowledge, develop over time. Zembal-Saul, Starr and Krajcik (1999) mention that pre-service teachers observing experienced teachers

during the practice teaching period, might maximise the quality of the pre-service teachers.

The research presented here was focused on the interaction between pre-service teachers and in-service teachers during a practice teaching period. We relied on the practical knowledge and PCK of teachers as the reference for making judgements on pre-service teachers' competencies in natural science teaching and thus their PCK. The questions (Appendix A) presented to the in-service teachers during the semi-structured interviews, guided their judgements of pre-service teachers. We analysed the data in terms of our framework developed from various authors as described in the next section. This article therefore reports on the study of in-service teachers' perspectives of pre-service teachers' knowledges of natural science teaching by applying Magnusson, Krajcik & Borko's (1999) criteria for PCK to interpret the comments made by the in-service teachers during the interviews.

Theoretical framework

Shulman originally conceptualised the construct of Pedagogical Content Knowledge (PCK) in 1986. The key elements in his definition are knowledge of representations of subject matter and the understanding of specific learning difficulties and student conceptions. Grossmann (1990) identified four distinct components of PCK: knowledge and beliefs for teaching subject matter; knowledge of students' understanding, conceptions and misconceptions of particular topics in a discipline; knowledge of the curriculum; and knowledge of instructional strategies and representations. In elaborating on these aspects, Magnusson, Krajcik and Borko (1999) conceptualised five criteria for PCK: orientations towards teaching science, knowledge and beliefs of science curriculum, knowledge of students' understanding of science, knowledge of assessment in science and knowledge of instructional strategies. According to Carlsen (1999), PCK is a form of teacher knowledge and it includes five general knowledge domains: general education context, specific education context, general pedagogical knowledge, subject matter knowledge and PCK. Figure 1 (adapted from Carlsen, 1999) represents a reformulation of science teacher knowledge as published by authors such as Shulman (1986), Grossman (1990), and Magnusson *et al*. (1999).

It follows therefore that to attain an understanding of science and the development of scientific knowledge while taking into consideration the needs of diverse groups of learners, teachers will have to display differentiated and integrated knowledge domains to effectively design and guide learning experiences. An opportune time to ascertain knowledge of a teacher or pre-service teacher's knowledge regarding teaching is during their practice teaching period as it is the induction period of pre-service teachers into teaching.

Carlsen (1999) mentions that the induction period to teaching is a "wonderful" time to examine teacher knowledge as it provides a space where conceptions of subject matter are manifested in "different places in different ways". It is therefore necessary to tap from the competence of the in-service teachers to 'judge' or make inferences about the knowledges regarding science teaching of our pre-service teachers.

In referring to statements and observations made by the in-service teachers, as well as questions they sometimes ask while teaching, Magnusson *et al*. (1999) quote the following: 'What shall I do with my learners to help them understand natural science?', 'What materials and resources are there to help me?', 'What are the learners' pre-knowledge about natural science? What do they find difficult?', 'How best shall I assess what my learners have learned?' They argue further that these questions, which describe pedagogical content knowledge (PCK), are central to identifying the knowledge that distinguishes the skilled in-service

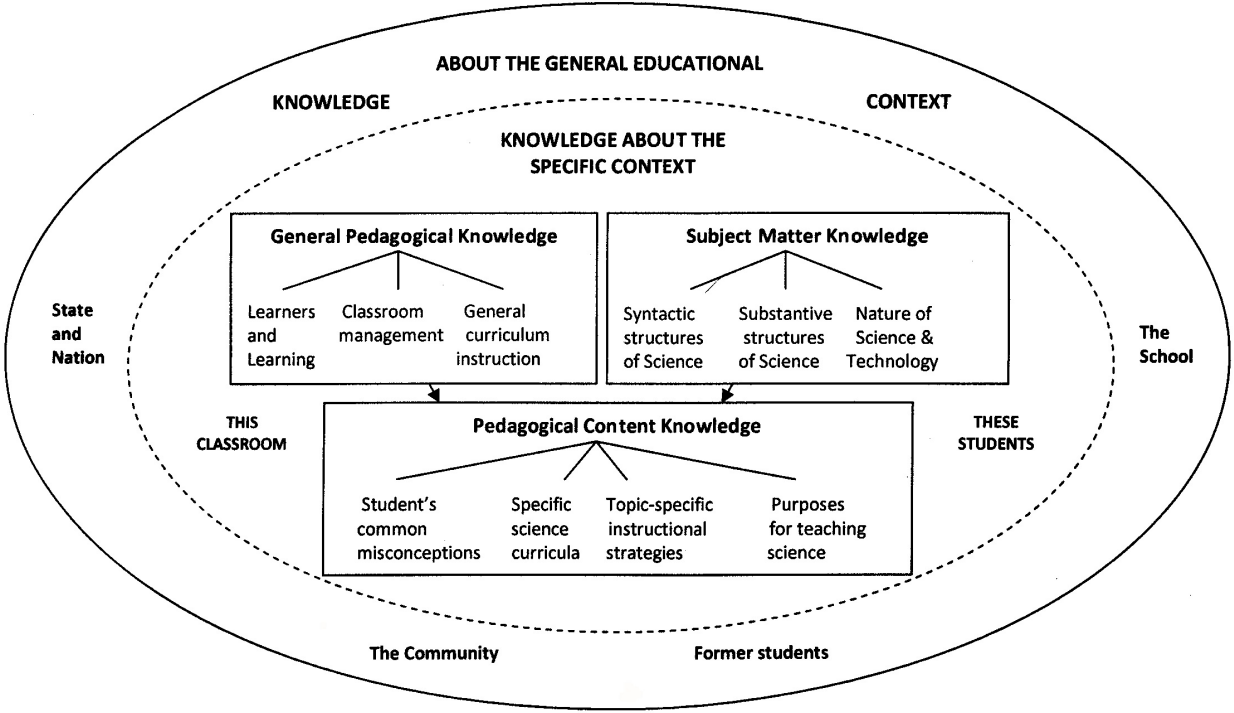

Figure 1 Domains of teacher knowledge (Carlsen, 1999)

teacher from the pre-service teacher (Shulman, 1986).

In our teacher education programme we teach the intended curriculum for schools as set out in the policy documents (RSA, 2000). Content areas and outcomes for natural sciences are highlighted and discussed in terms of the national curriculum. In this way we deal with curriculum as policy and the intended curriculum for schools. Professional education includes the roles for teachers and the competencies as presented in the policy documents. During our analysis of the documents we were able to link some of the prescribed roles for teachers to the criteria for PCK as presented by Magnusson *et al*. (1999)(Table 1, Appendix B).

The concept of PCK is mostly theoretical and has not actively been introduced into our teacher training programme or applied in schools. For this reason the concept seemed to be far removed from the daily practice and conceptual framework of in-service teachers. Therefore the questions formulated for the interviews consisted of separate concepts for content knowledge, knowledge of pedagogy and knowledge of curriculum concerning the pre-service teachers as related by the in-service teachers. The concepts of PCK developed by Shulman (1986), Grossman (1990) and Magnusson *et al*. (1999) were used to develop an analytical framework which was considered during the thematic analysis of the taped and transcribed interviews.

Policy documents focusing on the changed pedagogy of both pre-service teachers and in-service teachers form the key to the transformation of teaching in South African schools and define the roles and competencies that the teacher must be able to perform. These roles include:

- Learning mediator;
- Interpreter and designer of learning programmes and materials;
- Leader, administrator and manager;
- Scholar, researcher and lifelong learner;
- Assessor;
- Learning area/subject/discipline/phase specialist.

Competencies related to these roles are foundational competency, practical competency and reflexive competency. These roles and competencies are crucial facets according to which knowledge, skills and values of a competent professional teacher will be identified (Norms and Standards, 2000).

Teachers' knowledge, beliefs and attitudes about education [natural science teaching] have a profound effect on all aspects of their teaching (Carlsen, 1991, 1993; Dobey & Schafer, 1984; Koster, Brekelmans, Korthagen & Wubbels, 2005; Nespor, 1987; Smith & Neale, 1991). Some of this research was framed by the conceptualisations developed by Shulman and his colleagues concerning the diverse domains that teachers use when planning and teaching (Grossman, 1990; Shulman, 1986). Two major contributions of this work were the acknowledgement of the importance of subject-specific knowledge in effective teaching, and the identification of a type of knowledge that was seen to be unique to the profession of teachers known as pedagogical content knowledge. These could be seen as developing from a teacher's knowledge of content and knowledge of pedagogy.

Although the concept of domains of knowledge (including PCK) has been used in education as a vehicle to understand how teachers conceptualise and organise their teachings, it seems to be not universally accepted as PCK. Many authors have placed knowledge in various categories resembling PCK. Examples of such categories are: domain knowledge (Carlsen, 1991; Hong *et al*., 2008), teacher competencies (Barnes & Nobles, 1999; Casey, 1999; Koster *et al*., 2005), academic knowledge and skills (Barnes & Nobles, 1999) and subject-oriented, methodological, communicative and organisational competencies (Korthagen, 2004). Accord-

ing to Stoof, Martens and Merrienboer (2000), competency is defined by the levels of integration of knowledge, skills and attitudes, which further define a good (natural science) teacher.

Table 1 (Appendix B) provides a summary of the five criteria for PCK as suggested by Magnusson *et al*. (1999), linked to the roles prescribed by the policy documents (RSA, 2000). These five criteria and roles relate to many of the categories previously shown in Figure 1.

Elements of overlap were found between the different knowledges, defining characteristics of PCK and the expectations of the policy documents regarding the roles and competencies of a good science teacher. It is therefore clear that the acquisition of PCK should start in the pre-service training phase of teachers (Lankford, 2010). However, the reality is that teachers hold inadequate conceptions of the nature of science, which may be translated as being positivist in the sense that they believe the substantive content of science is fixed and unchangeable rather than tentative (Van Driel, Verloop & De Vos, 1998). The effect of this is that natural science is presented to learners by teachers as a body of knowledge with proven facts and truths, and students ultimately focus on memorising facts, with the result that they lack the intellectual skills in science to allow them to assume their roles in society adequately (Syh-Jong, 2007).

Goodnough (2006) points out that at the end of their teacher training course in natural science, pre-service teachers are expected to comply with required skills, attitudes and dispositions in order to deal with the ongoing adaptations in the classroom environment. This statement can also be related to the educational environment in South Africa. If their roles and competencies as teachers are not adequately developed, pre-service teachers will be ill prepared to commence their roles as competent teachers.

Research design

Drawing on both the criteria for PCK (Magnusson *et al*., 1999) and the content of the policy documents, semi-structured interview questions were constructed and administered to in-service natural science teachers

Context

The study was conducted within a larger project whose purpose was to adapt the BEd course for teachers to align with the curriculum requirements for education as set out in the policy documents of the Department of Education. This exploratory study was done in collaboration with in-service teachers to establish their perspectives on our students' 'performance'. The concept of PCK was chosen, as this approach links to the roles for educators in the policy documents and the requirements thereof for our teachers and teachers in training. This specific research purpose was to ascertain the different levels or domains of knowledge displayed by pre-service teachers as perceived by their in-service teacher mentors during teaching practice at different primary and secondary schools. As in-service teachers are often not familiar with the term PCK, questions discussed during the interviews were formulated in relation to the different domains of knowledge (Carlsen, 1999) from which data were generated. Pre-interview discussions were held regarding the policy documents and the teachers understanding of the norms and standards.

Sample

The method of sampling for this study may be termed purposive sampling, since the participants were chosen with specific criteria in mind. Pre-service teachers conducted their practice

teaching at schools with learners from different socio-economic groups, as well as co-ed and single-gender schools. The teacher participants were selected on the basis that they were expert mentors assigned to the pre-service teachers, whose understanding of the different knowledges within natural science teaching were being investigated. We are of the opinion that the expert mentors are experienced teachers whose domains of knowledge enable them to teach well. These in-service teachers were identified as expert mentors regarding their teaching experience and qualifications; BEd degree or HDE (higher diploma in education). They also form part of the learning community established between the schools where pre-service teachers do their teaching practise and our institution of higher education. Learning communities are important for support, interaction as well as networking between new teachers, experienced teachers [expert mentors] and teacher educators (Etkina, 2010) These expert mentors were required to do some of the teaching assessments and observe the pre-service teachers who were presenting natural science lessons that they were required to teach during teaching practice. This included observation of teaching methods, content area accuracy, practical competencies and dealing with diversity in classrooms according to observation schedules supplied by the institution. The sample for this study consisted of in-service teachers at four secondary schools and two primary schools, which were sampled purposively to reflect the disparate socio-economic status of different communities and schools in South Africa, and to accommodate the possible differences between single-gender and co-ed schools.

The 11 participants consisted of in-service teachers from the various schools where our pre-service teachers were placed for teaching practice for a period of nine weeks: six female teachers and five male teachers. Six schools were selected: two primary and four secondary schools. Secondary schools were chosen according to the socio-economic status of the communities that the schools served and also whether they were single-gender (two schools) or co-ed schools (two schools). The segregated boys' and girls' schools were academically top-performing schools, while the one co-ed school served middle to upper middle-class communities and the other a lower to middle-class community.

Both the primary schools were co-ed schools. One school was unofficially qualified as serving an upper middle-class community; the other school served a lower middle-class community consisting mainly of the economically disadvantaged groups.

For the purposes of this study, the schools are referred to as School A, B, C, D, E and F, to ensure anonymity as well as for ethical reasons.

Data collection and analysis

Given the exploratory nature of this study and the fact that the aim of the study was to ascertain some perspectives of in-service teachers regarding the performance of the pre-service teachers assigned to them, the semi-structured interview method was considered to be the most appropriate. The argument in favour of the appropriateness of interviews for this specific study is supported by Denscombe (2007:109-138), who notes that the interview is suitable for investigating subtle and more complex phenomena that may consist of sensitive information of a personal nature as well as for accessing privileged information from certain individuals willing to furnish the researcher with this kind of information: "… the interviewer still had a clear list of issues to be addressed and questions to be answered … the interviewer is more flexible in terms of the order which the topics are considered … to let the interviewee develop ideas and speak more freely …"

Permission was obtained from the Western Cape Education Department to conduct the semi-structured interviews at the identified schools with the chosen in-service teachers, who

signed a consent of participation form. All the interviews were audio-taped and transcribed; field notes were also taken during and after interviews to identify common topics within the responses. Teachers were assured of confidentiality and anonymity as agreed during the initial pre-interview discussion.

The first step in analysing the data was following processes of Thematic Analysis as discussed by Braun and Clark (2006). These data, gathered from the semi-structured interviews, were coded according to the responses of the in-service teachers and linked to the criteria for PCK as outlined in Table 1 (Appendix B). Labels were assigned to the units of text from the transcripts and field notes that most closely resembled the mentioned criteria for PCK. A process of comparison was engaged concerning the responses of the different teachers at the various schools visited. These responses were finally grouped into the same conceptual categories represented by the different criteria for PCK, and documented. Links were established between the criteria and the findings from the interviews and these will be discussed in the following section.

Results and discussion of the results

The results were linked to the five criteria for PCK as described by Magnusson *et al*. (1999). These served as a framework for analysis of opportunities for PCK in the school curriculum and to recognise the level of pre-service teachers' experience of PCK (different knowledge domains) in the context of the curriculum. The findings displayed that the students complied with some of Magnusson *et al*.'s (1999) criteria for PCK and were lacking in others. Etkina (2010) argues that some aspects of PCK could only be formed during the preparation years of a teacher and that each teacher develops their own PCK with teaching experience. Thus, it became evident during this study that the development of sound PCK is crucial during the training of pre-service teachers, as also emphasised in the policy documents.

The awareness of the in-service teachers regarding the above criteria and their perspectives of the pre-service teachers are reflected in the following discussion.

According to the first criterion, orientations toward teaching science are generally organised according to the emphasis of the instruction, content and resource material, on a continuum from purely process- or content-based to that of being inquiry-based [problem-solving]. It became clear from the interviews conducted with in-service teachers that pre-service teachers are mostly content-driven and that they struggle to translate the theory into practice (schools A, B, C, D and F). However, in one school (school F) the teachers felt that the students were too content-driven, and then sometimes did not pay attention to the nature of the learners. Only school E mentioned that there might be 'gaps' in their (pre-service teacher) content knowledge. The responses from the in-service teachers were linked to criterion 1 for PCK as described by Magnusson *et al*. (1999). The responses are quoted verbatim and some were translated from Afrikaans, as indicated in each relevant instance.

> *The girl that was here was over and above on her knowledge, she was fantastic*.
> *One provides the content they have to do but they do a lot of research. The content knowledge is definitely there*. (Translated from Afrikaans)
> *In connection with the curriculum and methods they are quite up to date; it is only the content knowledge that needs experience*. (Translated from Afrikaans)
> *The students have a positive attitude ... they do not necessarily have all the subject knowledge, but they know where to find it*. (Translated from Afrikaans)
> *The application of the skills that they learn to the practical part is not yet completely evident, that is the translation of theory to practice*. (Translated from Afrikaans)

In the beginning he just tries to transfer the theory. (Translated from Afrikaans)

The university students were very content-driven and very task-oriented. (Translated from Afrikaans)

Pre-service teachers demonstrate an understanding of science and science knowledge, although it is felt that pre-service teachers are up to date with the curriculum and methodology, there seems to be some lack of subject content knowledge. Furthermore it is mentioned that pre-service teachers find information and resource material to fulfill the role of interpreter and designer, manager and administrator.

The second criterion, knowledge of science curriculum, consists of two parts: (1) the knowledge of goals and objectives, which includes knowledge of national documents that outlines frameworks for decision making, and (2) knowledge of programmes that are relevant to a particular domain of science. Concerning the first part, the in-service teachers seemed to agree that some of the pre-service teachers had acquired and were up to date with all the necessary knowledge concerning the curriculum and national documents (schools B and E), as can be derived from the following quotes. Schools A, C, D and F felt that pre-service teachers need more up-to-date knowledge about national documents:

Regarding the curriculum and methods, they appear to be quite up to date. (Translated from Afrikaans)

They have knowledge of the curriculum. (Translated from Afrikaans)

I feel that they do not necessarily have knowledge of the curriculum when they arrive here, but they do ask about it. (Translated from Afrikaans)

However, regarding the second part, the knowledge of programmes that are relevant to a particular domain, the perceptions of the in-service teachers showed a lack of understanding and knowledge in one of the specific domains (schools D, E and F) of the natural science curriculum, namely 'Earth and Beyond', which has a distinct characteristic of geography:

If I did not have geography at school until matric, I would have struggled with 'Earth and Beyond', which is more geography … (Translated from Afrikaans)

The above weak point/deficiency was raised as a concern from a novice in-service teacher who had completed her teacher training the previous year. In support of the points made regarding the specific domain of 'Earth and Beyond', the experienced in-service teachers voiced a similar concern illustrated in the following comments:

The part of the learning areas that needs more attention is the one on 'Earth and Beyond', which is actually part of geography and biology, this part is thus being neglected and needs more attention. The students seem to be wary of this area. (Translated from Afrikaans)

It is clear that policy documents are consulted and that there is an understanding of the prescribed curriculum. Certain learning areas are of concern as this is neglected during the pre-service training and need more attention. This links to the role of educator and subject specialist which will develop more over time and with experience (Etkina, 2010).

The third criterion for PCK refers to the knowledge of learners' understanding of science with the characteristic of the teacher having the knowledge about students to help them develop scientific knowledge. It consists of two parts: (1) knowledge of requirements for learning, including prerequisite knowledge and approaches to learning, and (2) knowledge of areas of learner difficulty, referring to topics learners find difficult to learn.

Teachers in schools A and B felt that pre-service teachers start to know how to react to different types of learners after conducting a few classes, although teachers in school C and F felt that the pre-service teachers need more skills to adapt to the needs of the different learners

and that they should pay more attention to whom the learners are as people. It is difficult to reconcile respect and discipline in diverse classes and teachers felt that they need more support in dealing with these issues.

> *They enquire as to what the children already know*. (Translated from Afrikaans)
> *With experience they [pre-service teachers] learn ... It [knowledge of discipline] comes with experience ...* (Translated from Afrikaans)
> *They must also be able to adapt to the different needs of the children, and be able to adapt to the type of child that they are working with*. (Translated from Afrikaans)
> *The discipline part needs more attention*. (Translated from Afrikaans)
> *They need [support or assistance with] on conflict management*. (Translated from Afrikaans)

According to two of the schools (schools A and E) difficulty is displayed in the topic of Electricity and Energy within the Natural Science curriculum, as the learners do not grasp the concept of an atom. There also seems to be difficulty in the link between learning areas as well; continuing with one topic in a specific learning area and not making a proper link to similar topics in another learning area creates misconceptions amongst learners (school E).

> *… you cannot tell a Gr 6 learner that electricity comes from nuclear power and the splitting of atoms if they do not know what an atom is …* (Translated from Afrikaans)
> *… you cannot jump from electricity to energy in plants ... learners do not understand it* …(Translated from Afrikaans)

According to Hong, Horng, Lin and ChanLin (2008), a disparity exists between pre-service teacher education and the in-service job requirements. It may therefore be inferred from the above comments recorded during this study that the pre-service teachers do not yet have the required awareness of learners' understanding of science and learning diffuculty and thus the pre-service teachers do not fully comply with this specific criterion of PCK and the role as mediator.

The fourth criterion is conceptualised in the knowledge of assessment, consisting of the knowledge of the dimensions of science learning to be assessed and the methods of assessment. In comments from the in-service teachers, emphasis is placed on the fact that the pre-service teachers need more training in the administering and use of assessment (schools C and D). Schools A and B indicated that pre-service teachers could not demonstrate assessment skills as their practice teaching period did not allow enough time. The teachers of school E felt that the assessment methods were too complicated even for them, and that they had to do too much administrative work and paperwork. Components like knowledge of assessment and knowledge of instructional strategies are of some concern as indicated by the following quotes:

> *Students must receive more training on how to assess and how to use it*. (Translated from Afrikaans)
> *Assessment and the design of rubrics leave an open space*. (Translated from Afrikaans)
> *… practicum time is too short, because the student has to take the learners from the beginning through to assessment in order to be able to understand it ... and ... short time of practicum does not allow them to assess it effectively*.
> *Assessment is a problem; it is a nightmare. There is too much paperwork, and then you start to neglect things, and choose only those that you want to do*. (Translated from Afrikaans)

It could be inferred that assessment seems problematic to experienced in-service teachers; therefore it may be more so for pre-service teachers, indicating a lack of training.

Adhering to the role of assessor is not reached satisfactorily. Pre-service teachers need a

better understanding in the designing and administering of various assessment strategies. In the fifth and final criterion, knowledge of instructional strategies, most of the emphasis of the in-service educators was on the categories of topic-specific activities and topic-specific representations. Concerning topic-specific activities it could be inferred that the knowledge of activities, especially experiments, seems to be sufficient (schools A, C, D and F) while the teachers from one school felt that the confidence of the pre-service teachers to engage with the experiments are lacking (school E):

> *One of the students was very afraid to work with gas*. (Translated from Afrikaans)
> *They do not have to know everything, but they have to seem at ease when they do it. They must be able to improvise*. (Translated from Afrikaans)

In-service teachers made favourable comments concerning topic-specific representation (criterion 5). The pre-service teachers were accessing technology and adapting to new pedagogy in order to prepare for their lessons more effectively and in doing so engaging with PCK by way of various knowledge domains. According to the teacher of school F, "students should gain more knowledge on the different ways of representing content, although they are good with new technologies".

> *Some of them have good Internet knowledge, and then plan interesting interactive tasks.* (Translated from Afrikaans)
> *It seems to me that they employ many forms of pedagogy*. (Translated from Afrikaans)
> *Students adapt well to the new pedagogy, because they make an effort to do research and obtain what they need to present a specific type of class*. (Translated from Afrikaans)

Pre-service teachers do fulfill the role of researcher and life-long learner as they make use of available resources to engage with "new" information and content, developing as subject experts.

It is evident from the results that some of the criteria for PCK, such as orientations toward teaching science, knowledge and beliefs of science curriculum and knowledge of students' understanding of science, are currently addressed in the programme. Some uncertainties are however displayed regarding other criteria: knowledge of assessment in science (criterion 4) and knowledge of instructional strategies (criterion 5). No links could be made with criteria 4 and 5 in some of the target schools (schools F and B, respectively). This indicates a lack of knowledge in the assessment of natural science as well as a lack of instructional strategies. These two criteria (4 and 5) make up part of PCK and therefore it could be inferred that pre-service teachers' levels of PCK are not fully addressed and developed during the pre-service science course in our programme.

Conclusion

The overarching goals of this study were to contextualise the importance of the different knowledge domains and the PCK development of pre-service teachers as well as an appraisal of PCK by in-service teachers. It was further aimed at providing a space to implement ideas on science teaching and teaching strategies in a real environment in which pre-service teachers will be working.

Generally it can be inferred from the data that pre-service teachers do not comply with all the knowledge domains and PCK that enable a teacher to teach well. A great deal of time and effort is needed before any change will become visible in in-service as well as pre-service teachers regarding their understanding of PCK (Etkina, 2010).

The analysis of the data and the ensuing discussion show clearly that the pre-service teachers complied only in terms of some of the criteria noted for PCK. According to the in-

service teachers it appears that the pre-service teachers had good content knowledge, but they did not always present the knowledge in innovative and creative ways as envisaged by the policy documents. Some of the pre-service teachers lacked the confidence to teach or do practical work. Pre-service teacher's confidence to teach effectively should develop during teacher training and this confidence will further develop over time and with experience (Hanuscin, Lee & Akerson, 2010; Lankford 2010). In addition, the pre-service teachers do have a sound understanding of curriculum ideas as presented in the DoE policy documents and they do understand the natural science subject content. The responses related to assessment indicated a lack of competence to implement various strategies of assessment and suggested that time is needed to develop these competencies. This implies that further refinement of PCK is related to time and teaching experience that carries on beyond pre-service teaching into career development.

Overall, the data produced shows that aspects of PCK seem to be developed to varying degrees within the pre-service teacher training course and largely in isolation of each other. Goodnough & Hung (2008) argue that problem-based learning (PBL) is an instructional approach that provides a means to foster meaningful science learning while enhancing PCK. Ideas developed regarding PBL show that PBL as a teaching and learning process provides space and opportunities for the development of a variety of skills, including conceptualisation and thinking, which might serve to better organise pre-service teachers with regard to fulfilling the roles set out in the policy documents and to utilise the many criteria of PCK as well as integrating the different domains of knowledge pertaining to good science teaching. It is our contention that using PBL as a basis for teaching will integrate the criteria of Magnusson *et al*. (1999) and provide the space for holistic PCK development and broadening of the domains of knowledge within natural science for pre-service science teachers. While this benefits the teaching of natural science it will enhance the development of teaching competencies and roles as stipulated in the norms and standards document for teachers.

Possibilities for a second research cycle based on literature (Chick & Harris, 2007; Hanuscin *et al*., 2010; Lankford, 2010) regarding engaging discussion about revisiting and rethinking science education as well as the adoption of PBL (Goodnough & Hung, 2008) as an instructional strategy for teaching and learning to enhance PCK in the curriculum is possibly a way forward. Challenges to be considered during the proposed second research cycle could include: (1) organisational challenges such as large classes with only one facilitator are of great concern, (2) cognitive challenges to provide students with a strong rationale for adopting a new instructional approach; (3) the constant search for ways to make problems engaging and meaningful; (4) constraints presented by rigid and slow-changing teaching and learning programme structures; (5) the lack and availability of qualified facilitators; and (6) time constraints.

> "To learn to be a good (highly qualified) teacher, the person needs to be exposed to different contexts and pre-service teachers need opportunities to practice their acquired skills within these contexts" (Etkina, 2010:4).

Considering the findings on the lack in some knowledge domains and PCK criteria regarding the teaching of natural science displayed by pre-service teachers emanating from this study, the benefits for teaching and learning in the form of PBL should now seem clearer. However, it would be beneficial to engage in a produced synergy of both the local and international contextual constraints while also being mindful of the challenges presented in the foregoing section.

PCK development is time dependent and requires mutualistic interaction between in- and

pre-service teachers and university supervisors. Close cooperation in this triadic partnership, we believe, will address the problems encountered in this study.

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References

Aitken JL & Mildon DA 1992. Teacher Education and the Developing Teacher: The Role of Personal Knowledge. In: Fullan M & Hargreaves A (eds). *Teacher Development and Educational Change*. The Falmer Press.

Agbo SA 2003. A Learning Community Model for Professional Development and

Transformational Teacher Education: Linking Teacher Preparation with In-Service Teacher Learning and School Improvement. In: Preston DS (ed.). *The Idea of Education*. Amsterdam, NY: Radopi.

Barnes S & Nobles D 1999. National Vocational Qualifications in England and Skills Standards in Texas. In: Hong J-C, Horng J-S, Lin C-L & ChanLin L-J 2008. Competency disparity between pre-service teacher education and in-service teaching requirements in Taiwan. *ScienceDirec*t. *International Journal of Education Development*, 28:4-20.

Braun V & Clark V 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3:77-101.

Carlsen WS 1991. Effects of new biology science teachers' subject-matter knowledge on curricular planning. *Science Education*, 75:631-647.

Carlsen WS 1993. Teacher knowledge and discourse control: Quantitative evidence from novice biology teachers' classrooms. *Journal of Research in Science Teaching*, 30:471-481.

Carlsen WS 1999. Domains of teacher knowledge. In: Gess-Newsome J & Lederman NG (eds). *Examining pedagogical content knowledge*. Dordrecht: Kluwer Academic Publishers.

Casey D 1999. Method and Procedure for Developing Competency Standards. Regency Institute of TAFE, Sydney. In: Hong J-C, Horng J-S, Lin C-L & ChanLin L-J 2008. Competency disparity between pre-service teacher education and in-service teaching requirements in Taiwan. *ScienceDirect. International Journal of Education Development*, 28:4-20.

Chick HL & Harris K 2007. *Pedagogical content knowledge and the use of examples for teaching ration*. AARE, Fremantle [Online] Available: www.aare.edu.au/07pap/chi07286.pdf . Accessed 22 Nov 2010.

Denscombe M 2007. *The good research guide: for small-scale social research projects*. Maidenhead, England: Open University Press.

Dobey DC & Schafer LE 1984. The effects of knowledge on elementary science inquiry teaching. *Science Education*, 68:39-51.

Etkina E 2010. Pedagogical content knowledge and preparation of high school physics teachers. *Physical Review Special Topics – Physics Education Research,* 6:1-26.

Goodnough K 2006. Enhancing pedagogical content knowledge through self-study: an exploration of problem-based learning. *Teaching in higher education*, 11:301-318.

Goodnough K & Hung W 2008. Engaging Teacher's Pedagogical Content Knowledge: Adopting a Nine-Step Problem-Based Learning Model. *The Interdisciplinary Journal of Problem-based Learning*, 2:61-90.

Grossman PL 1990. *The making of a teacher: teacher knowledge and teacher education* . New York: Teachers College Press.

Hanuscin DL, Lee MH & Akerson VL 2010. Elementary Teachers' Pedagogical Content Knowledge for Teaching the Nature of Science. Science Teacher Education. [Online] Available: http://onlinelibrary.wiley.com . Accessed 2 Nov 2010.

Hong J-C, Horng J-S, Lin C-L & ChanLin L-J. 2008. Competency disparity between pre-service teacher education and in-service teaching requirements in Taiwan. *ScienceDirect. International*

Journal of Education Development, 28:4-20.
Korthagen F 2004. In search of the essence of a good teacher: toward a holistic approach in teacher education. *Teacher and Teacher Education*, 20:77-97.
Koster B, Brekelmans M, Korthagen F & Wubbels T 2005. Quality requirements for teacher educators. *Teaching and Teacher Education*, 21:157-176.
Lankford DM 2010. Examining the Pedagogical Content Knowledge and Practice of Experiences Secondary Biology Teachers for Teaching Diffusion and Osmosis. Doctoral dissertation, Faculty of the Graduate School, University of Missouri. [Online] Available: http://mospace.umsystem.edu
Magnusson S, Krajcik J & Borko H 1999. Nature, sources and development of pedagogical content knowledge. In: Gess-Newsome J & Lederman NG (eds). *Examining pedagogical content knowledge*. Dordrecht: Kluwer Academic Publishers, 95-132.
Nespor J 1987. The role of beliefs in the practice of teaching. *Journal of Curriculum Studies*, 19:317-328.
Norms and Standards 2000. [Online] available: www.polity.org.za/html/govdocs/notices/2000 Accessed 23 June 2008. http://academic.sun.ac.za/mathed/174/NORMS%20AND%20 STANDARDS%20FOR%20EDUCATORS.pdf Accessed 16 February 2010.
RSA 2000. South African Government Information. [Online] Available: http://www.info.gov.za/speeches/2000 . Accessed on 23 June 2008 and http://www.info.gov.za/view/DownloadFileAction?id=66234 Accessed 16 Feb 2010.
Shulman LS 1986. Those who understand knowledge growth in teaching. *Educational Researcher*, 15:4-14.
Sikes PJ 1992. Imposed Change and the Experienced Teacher. In: Fullan M & Hargreaves A (eds). *Teacher Development and Educational Change*. The Falmer Press.
Smith DC & Neale DC 1991. The construction of subject-matter knowledge in primary science teaching. In: Brophy J (ed.). *Advances in research on teaching (2)*. Greenwich, CT, JAI Press.
Stoof A, Martens RL & Merrienboer JJG 2000. What is competence? A constructivist approach as a way out of confusion. In: Hong J-C, Horng J-S, Lin C-L & ChanLin L-J. 2008. Competency disparity between pre-service teacher education and in-service teaching requirements in Taiwan. *ScienceDirect. International Journal of Education Development*, 28:4-20.
Syh-Jong J 2007. A study of students' construction of science knowledge: Talk and writing in a collaborative group. *Educational Research*, 49:65-81.
Van Driel JH, Verloop N & De Vos W 1998. Developing Science Teacher's Pedagogical Content Knowledge. *Journal of Research in Science Teaching*, 35:673-695.
Zembal-Saul C, Starr ML & Krajcik JS 1999. Constructing a Framework for Elementary Science Teaching using Pedagogical Content Knowledge. In: Gess-Newsome J & Lederman NG (eds). *Examining Pedagogical Content Knowledge: The construct and its Implications*. Kluwer Academic Publishers.

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Appendix A

Open-ended questions presented to participants during the semi-structured interviews. Discussions were audio taped and transcribed.

1. Are you familiar with the content of the document pertaining to the Norms and Standards for educators documented in the Government Gazette 2000?
2. Are you familiar with the prescribed roles for educators set out in the Norms and Standards? (a copy of the roles were supplied and discussed during a pre-interview discussion)
3. Did the pre-service teachers display and/or apply any of these roles and principles during their teaching practice?
4. Did the pre-service teachers apply newly acquired pedagogical skills and/or instructional strategies?
5. Did the pre-service teachers display a deep understanding of science and science content knowledge?
6. What is your opinion about the assessment of content outcomes?
7. Do you feel that the pre-service teachers' understanding of the Science curriculum is efficient enough to be put to use in a school/classroom?
8. Do the pre-service teachers engage with knowledge about the different learners in order to maintain good discipline in a diverse classroom and to identify problem areas?

Appendix B

Table 1

Criteria for PCK (Magnusson *et al*., 1999)	**Roles for educators** (Norms and Standards, 2000)
1. *Orientations toward teaching science*: • They reflect a teacher's knowledge and beliefs about the purposes and goals of teaching in a particular grade. This serves as a conceptual map that guides instructional decisions about issues such as daily objectives, the content of assignments, the use of textbooks and other materials and the evaluation of student/learner learning. • They represent a general way of viewing or conceptualising science teaching.	*Interpreter and designer of learning programmes and materials* • The educator will understand and interpret provided learning programmes, design original learning programmes, identify the requirements for a specific context of learning and select and prepare suitable textual and visual resources for learning. The educator will also select, sequence and pace the learning in a manner sensitive to the differing needs of the subject/learning area and learners. *Leader, administrator and manager*: • The educator will make decisions appropriate to the level, manage learning in the classroom, carry out classroom administrative duties efficiently and participate in school decision making structures. These competences will be performed in ways which are democratic, which support learners and colleagues, and which demonstrate responsiveness to changing circumstances and needs.
2. *Knowledge and beliefs of science curriculum*: • These are the mandated goals and objectives which include knowledge of national level documents, outlining the science curriculum and instructional methods, and • knowledge of specific curricular programmes which include programmes and materials that are relevant to teaching a particular domain of science and specific topics within that domain.	*Interpreter and designer of learning programmes and materials* • The educator will understand and interpret provided learning programmes, design original learning programmes, identify the requirements for a specific context of learning and select and prepare suitable textual and visual resources for learning. The educator will also select, sequence and pace the learning in a manner sensitive to the differing needs of the subject/learning area and learners.

Table 1 (continued)

	Learning area/subject/discipline/phase specialist • The educator will be well grounded in the knowledge, skills, values, principles, methods, and procedures relevant to the discipline, subject, learning area, phase of study, or professional or occupational practice. The educator will know about different approaches to teaching and learning (and, where appropriate, research and management), and how these may be used in ways which are appropriate to the learners and the context. The educator will have a well-developed understanding of the knowledge appropriate to the specialism.
3. *Knowledge of student's understanding of science*: • This refers to knowledge of requirements for learning which include teachers' beliefs and knowledge about prerequisite knowledge for learning specific scientific knowledge as well as students' variations in their approaches to learning. • It also includes knowledge of areas of student difficulty, which refers to teacher's knowledge of the science topics that students find difficult to learn.	*Learning mediator* • The educator will mediate learning in a manner which is sensitive to the diverse needs of learners, including those with barriers to learning; construct learning environments that are appropriately contextualised and inspirational; communicate effectively showing recognition of and respect for the differences of others. In addition an educator will demonstrate sound knowledge of subject content and various principles, strategies and resources appropriate to teaching in a South African context.

Table 1 (continued)

4. *Knowledge of assessment in science*: • This aspect refers to knowledge of the dimensions of science learning that are important to assess, including knowledge of the aspects of students learning that are important to assess within a particular unit of study, with a specific focus on the concept of scientific literacy. • It also refers to knowledge of the methods by which the particular learning can be assessed, with a focus on the methods that might be employed to assess specific aspects of student learning that are important to a particular unit of study.	*Assessor* • The educator will understand that assessment is an essential feature of the teaching and learning process and know how to integrate it into this process. The educator will have an understanding of the purposes, methods and effects of assessment and be able to provide helpful feedback to reamers. The educator will design and manage both formative and summative assessment in ways that are appropriate to the level and purpose of the learning and meet the requirements of accrediting bodies. The educator will keep detailed and diagnostic records of assessment. The educator will understand how to interpret and use assessment results to feed into processes for the improvement of learning programmes. *Learning area/subject/discipline/phase specialist* • The educator will be well grounded in the knowledge, skills, values, principles, methods, and procedures relevant to the discipline, subject, learning area, phase of study, or professional or occupational practice. The educator will know about different approaches to teaching and learning (and, where appropriate, research and management), and how these may be used in ways which are appropriate to the learners and the context. The educator will have a well-developed understanding of the knowledge appropriate to the specialism.

Table 1 (continued)

5. *Knowledge of instructional strategies*: • This refers to subject-specific strategies, which are related to the orientations to teaching science, and specifically to teaching science as opposed to other subjects, and • knowledge of topic-specific strategies, which are much narrower in scope and apply to particular topics within the domain of science.	*Scholar, researcher and lifelong learner* • The educator will achieve ongoing personal, academic, occupational and professional growth through pursuing reflective study and research in their learning area, in broader professional and educational matters, and in other related fields. *Learning area/subject/discipline/phase specialist* • The educator will be well grounded in the knowledge, skills, values, principles, methods, and procedures relevant to the discipline, subject, learning area, phase of study, or professional or occupational practice. The educator will know about different approaches to teaching and learning (and, where appropriate, research and management), and how these may be used in ways which are appropriate to the learners and the context. The educator will have a well-developed understanding of the knowledge appropriate to the specialism.