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# 9. LEARNING FROM A LEARNING STUDY

*Developing Teachers' PCK through Collaborative Practices*

## PEDAGOGICAL CONTENT KNOWLEDGE IN FRAMING TEACHER KNOWLEDGE

The inherent complexity of teacher knowledge, and hence teacher learning, has been well documented in science education research literature (e.g. Nilsson, 2008; 2014; Loughran, Mulhall, & Berry, 2006). In order to teach science in ways that promote students' understanding, Shulman (1986, 1987) claimed that teachers need pedagogical content knowledge (PCK), a special kind of knowledge that teachers have about how to teach particular content to particular pupils. PCK was originally developed to represent one of the professional knowledge bases that an expert teacher possesses, and was later described as representing "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). Hence, PCK has become a way of understanding the complex relationship between pedagogy and content through an integrated process rooted in classroom practice (Van Driel et al. 1998).

Schneider and Plasman (2011) noted that PCK is a "heuristic for teacher knowledge that can be helpful in untangling the complexities of what teachers know about teaching and how it changes over broad spans of time" (p. 533). According to Park & Oliver (2008), PCK development means the development of individual components of PCK or the integration of these components to linking one with another. Another approach to conceptualising PCK is to explore all the components in a model, like in the study by Park and Chen (2012). The authors used a pentagon model (Park & Oliver, 2008) comprising five components: (a) Orientations Toward Teaching Science; (b) Knowledge of Students' Understanding in Science; (c) Knowledge of the Science Curriculum; (d) Knowledge of Instructional Strategies and representations; and (e) Knowledge of Assessment of Science Learning. Park and Chen (2012) argued that understanding the interactions between the components of broader PCK would foster the development of a more holistic perspective of the construct, something that is also useful for our thinking about the linkage between the different knowledge bases that together comprise PCK.

Ever since Shulman established the concept, many researchers have come to believe that PCK is an important topic in science education, and that high levels of

*M. Grangeat (Ed.), Understanding Science Teachers' Professional Knowledge Growth, 155–168.*

PCK will predict high levels of student achievement (Abell, 2007). In her review, Kindt (2009) noted that if we can identify PCK as the knowledge a teacher uses in the teaching process, our understanding of what 'good science teaching' looks like and how to develop this more consistently might be enhanced. Yet, since few concrete examples of PCK exist in the literature this has been a difficult task (Nilsson & Loughran, 2012). The varied perspectives on PCK have, however, strengthened the value of the construct in many ways, in particular for implementation in science teacher development programmes (Abell, 2008).

But how can teachers develop their understanding of PCK in order to make a difference in students' learning? And what is the linkage between teachers' more general knowledge (often defined as pedagogical knowledge, PK) and the topic-specific pedagogical content knowledge (PCK)? Although there is no universally accepted conceptualisation of PCK, there seems to be a consensus that PCK is to be distinguished from subject-matter knowledge (CK) on one hand, and from general pedagogical knowledge on the other. It is reasonable to suggest that PCK goes beyond subject matter knowledge (SMK) as it not only refers to the subject matter but also to the teaching of a subject in ways that promote students' understandings. Hence, a teacher needs to have deep knowledge of content (CK), as well as pedagogical knowledge (PK) and an orientation towards teaching content to students in a specific context. Despite the numerous definitions described above, there is little doubt that the complexity of teaching highlights the need for more extensive research into the relationships between the different elements that constitute teacher knowledge, and how these are developed and supported.

One way for teachers to develop their professional knowledge with a focus on specific science content and the ways students learn such content is through being involved in researching their own practice in a learning study (Marton, 2014; Marton & Pang, 2006; Pang & Ling, 2012; Runesson, 2008). A learning study is a collegial process in which teachers work together with a researcher to explore their own teaching activities in order to identify what is critical for their students' learning. In a learning study, the conditions for students' learning are identified and reflected upon. Such awareness is important in terms of PCK as it focuses on the relationship between the content, the teaching and students' learning. A learning study is a cyclical process (see Figure 1) in which teachers reflect on the necessary conditions for learning a specific content and how to meet these conditions in the learning situation.

This chapter aims to renew the perspectives about the linkage between PK, SMK and PCK by referring to a project in which three teachers were engaged in collaboration and critical reflection on their teaching of science in a learning study. It stresses that teacher collaboration, and particularly interactions between teachers, may underpin the development of PK, CK and PCK. The research question that frames the study is: "How does science teachers' learning about science teaching (PCK) develop as a shared practice by participating in a learning study?". As such, the project aims to investigate how teachers' professional knowledge of teaching is enhanced and, further, how students' learning might be developed as a consequence.

With its particular focus on *learning,* a learning study differs from the Japanese lesson study (Lewis, Perry, & Murata, 2006; Yoshida, 1999) where teachers can test hypotheses about good instruction, experiment with classroom practice, collect and analyse data from the classroom and thereby use the classroom as a laboratory for learning. Lewis, Perry and Hurd (2009) examined a lesson study in the USA and reported on teacher changes in motivation and capacity to improve instruction, in mutual accountability, shared goals for instruction and a common language for analysing instruction. However, the extent to which such experiences have impacted on the individual teacher's classroom practice outside the community of practice is seldom reported. In a modified version – the learning study (Marton & Pang, 2003) – in which the teachers in the current study participated, has an additional element to assess how their actions affect *learning* (teachers and students) as an effect of teachers' collaboration and critical reflections. Therefore, an important aspect of the learning study is that it pays attention to how the teachers' collective construction of professional knowledge is enacted by making a shift from professional development as something that is done *to* the teachers toward considerations of professional *learning* which entails the work *with* and *by* teachers in collaborative settings (Nilsson, 2014).

## COLLABORATIVE REFLECTION TO STIMULATE THE DEVELOPMENT OF TEACHERS' PROFESSIONAL KNOWLEDGE

Even though the development of PCK is well explored in the research literature, there is still more to be presented on how it can be developed and enhanced through different forms of collaborative reflections. In this section of the book, all three authors highlight collaborative reflection as a way to make the tacit knowledge of teachers explicit. The chapter by Isabelle Kermen addresses how experienced and beginning teachers work together to develop their professional knowledge by sharing and discussing their lesson plan and goals before implementing them. Kermen also describes the importance of collective reflections on classroom teaching in order to analyse teachers' choices and actions and the students' behaviour.

Through a careful reflection on the combination of PK and PCK, Michel Grangeat's chapter indicates how teachers' professional knowledge can be strengthened through teaching experience, professional development and teacher collaboration. In the chapter, teachers are interviewed about a videotaped lesson they have just carried out. The study leads to support the idea that teacher involvement in a collaborative setting entails a set of professional knowledge that is more balanced between general and content-specific and more open to learners' needs and interests.

Suzanne Kapelari reports on design-based research applied in a European project that valued the innovative potential of making tacit knowledge explicit while aiming to improve the practitioner's ability to teach science inquiry. In her chapter, Kapelari focuses on how PSCK development was supported by focusing on the interaction between tacit and explicit knowledge embedded in reflective learning cycles. The on-going interaction between individual professionals and the community led to shared knowledge of the group which finally offered the participants the opportunity to confirm, interconnect and develop their professional knowledge. All three chapters provide evidence of how collaborative settings among teachers might contribute to the development of pedagogical knowledge as well as pedagogical content knowledge for science teaching.

Recently, in their argumentation on teachers' professional development focusing on PCK, Van Driel and Berry (2012) highlighted the importance of "forms of professional development for teachers that are built on collaboration, collegial interaction and the fostering of relationships" (p. 26). These arguments are strongly supported in the international discussion on building teacher professional knowledge coming out of the recent THALIS report from the OECD (2015). For instance, Schleicher (2015) reports how collaboration among teachers, whether through professional learning or collaborative practices, is related to higher levels of both self-efficacy and job satisfaction. In particular, teachers who report that they participate in collaborative professional learning activities five times a year or more also report significantly higher levels of self-efficacy (in almost all countries) and greater job satisfaction (in two out of three of the participating countries/economies).

Although an increasing number of professional development activities for teachers are structured around collaboration, more evidence is needed on the conditions for successful collaboration and the development of teacher knowledge related to collaborative practices. Yet researchers have described a myriad of different structures and processes to create a collaborative culture among teachers in schools (Erickson et al., 2005; Nelson et al., 2008). Empirical evidence shows that collaboration among teachers may enhance their efficacy which, in turn, may improve student achievement and sustain positive teacher behaviours (Liaw, 2009; Puchner and Taylor, 2006). In a meta-review of empirical studies, Cordingley et al. (2003) reported that collaborative professional development is related to a positive impact on teachers' range of teaching practices and instructional strategies and to their ability to match these to their students' needs. Further, Harrison et al. (2008) suggested that effective professional development needs to provide an opportunity for teacher reflection and learning about how new practices can be developed or shaped from existing classroom practice. This requires teachers to re-examine what they do and how they might do it differently (Harrison et al., 2008). There is also evidence that collaborative professional development activities are linked to a positive influence on student learning processes, motivation and outcomes. For example, Hattie (2009) argued that teachers' professional knowledge of teaching (i.e. PCK) is the most crucial factor for student learning.

According to both research and policy, there is no doubt that learning about and understanding the complexities of teaching is important. Desimone (2009) stated that teachers experience a range of activities and interactions that may increase their knowledge and skills and improve their teaching practice as well as contribute to their personal, social and emotional growth as teachers. As professional learning is personal and appropriately shaped and directed by each of us as individuals (Loughran, 2010), teachers themselves must be committed to changing their own practice. Teachers' professional learning requires opportunities for teachers to be engaged as learners and to further reflect on how the process of framing and reframing practice might result in a personal understanding that can be translated in their own context. Introducing and exploring the academic construct of pedagogical content knowledge (PCK) is one way in which these complexities and the relationships between PK, CK and PCK can be explored. By having teachers involved in a study that forces them to explicitly engage with and explore their own developing PCK, it is envisaged that they might develop a deeper conceptual understanding of what it means to teach and learn, and ultimately lead to a heightened awareness of the complexities of teaching. This aligns well with Van Driel and Berry (2012) who argue that providing teachers with specific input (e.g. to collectively reflect on key notions of teaching and learning a specific topic) can contribute to their PCK.

## CONTEXT OF THE LEARNING STUDY

During one semester, three secondary science teachers and a science education researcher (the author) worked together in a learning study in which the object of learning was to understand the concept of ion and how ions are formed. The students were in grade eight (aged 14–15) and had previously been taught about the atom and the atomic structure, but not yet about ions. All three teachers were experienced science teachers, had worked together for several years and had volunteered to participate in the project. During the learning study, data were collected from video-recorded lessons and stimulated recall sessions in which the teachers and the researcher reflected on the lessons to analyse how the teachers developed knowledge of students' learning and the impact of that knowledge on their own teaching. The learning study started with the teachers identifying the 'object of learning' (ions and how ions are formed). Then, the students' prior knowledge and their existing perceptions were investigated with a pre-test. The teachers, together with the researcher, then analysed the test to provide an insight into how students experience what is to be learned and that which is critical (critical features) in order to learn about ions and how ions are formed. The variation in how the students experienced what was to be learned then became a source of planning the first lesson. Following that, the first teacher conducted the lesson (lesson 1) that was video-recorded.

After the lesson, the students were given a post-test in order to provide an insight into how the students' understanding of the object of learning had changed (or not) after the instruction. The three teachers and the researcher collaboratively analysed the video-recorded lesson (lesson 1) together with the pre- and post-tests in a stimulated recall session (Nilsson, 2008, 2014) in order to share their experiences of the lesson with a focus on evidence of student thinking and analysis of the teacher's instruction. Then, in the next phase of the learning study the second teacher conducted the (revised) lesson with his/her class (lesson 2) and the same procedure with analysis of the lesson and the post-test was repeated. Finally, the third teacher conducted the (again revised) lesson with his/her class and the lesson together with the post-test was analysed. As such, the learning study was an iterative process of planning, analysing and revising a lesson with the aim to improve both the students' and teachers' learning.

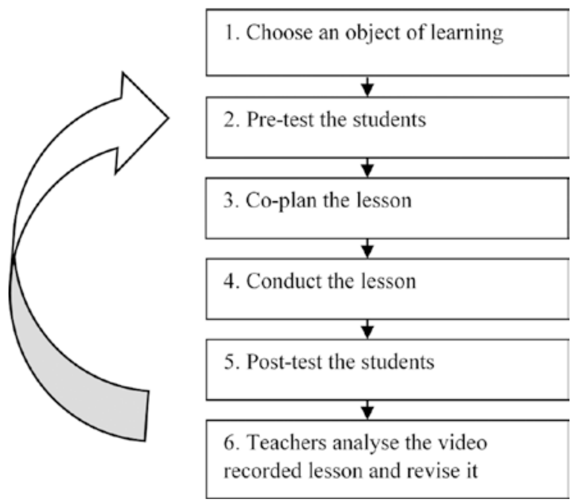


*Figure 1. Steps in the learning study*

In the learning study, the researcher's role was to stimulate the teachers to identify and communicate important aspects within their teaching and encourage them in their planning and revising of the lessons. The learning study lasted for almost a whole semester and the team had five meetings to plan, analyse and revise the specific lesson on ions. There was also a final meeting to discuss the findings and what the teachers had learned from the project. Every meeting lasted for about two to three hours.

- *Meeting 1*: Discussing the object for learning and designing the pre-test
- *Meeting 2:* Analysing the pre-test and planning the lesson
- *Meeting 3:* Analysing the post-test and stimulated recall reflection on lesson one to revise the lesson
- *Meeting 4:* Analysing the post-test and stimulated recall reflection on lesson two to revise the lesson
- *Meeting 5:* Analysing the post-test and stimulated recall reflection on lesson three
- *Meeting 6:* Final reflections on the whole process

The data analysis involved two steps. First, and most importantly, the video-recorded PCK test-lessons were analysed with a sharp focus on how the teachers enacted the specific content in the lesson and how their teaching had changed (or not) between the two lessons. Second, the transcribed tape recordings were analysed through content analysis (applied in the way described by Miles & Huberman, 1994) in order to identify changes in the teachers' ways of reflecting on their teaching. A content analysis of this kind is based on the view that it facilitates the production of core constructs from textual data (e.g. a systematic method of data reduction; data display; and conclusion drawing and verification). Through content analysis, data from all six meetings were read repeatedly in order to identify recurring themes and produce thick descriptions (Miles & Huberman, 1991; Geertz, 1973) of the experiences, tensions and emotions raised by the teachers.

## RESULTS

To give an insight into how the teachers developed different aspects of their PCK during the process (meetings 1–6), the three categories that derived from the data are presented below.

### *To Focus on the Content and Identify Critical Features for Students' Learning*

During the first meeting, together with the researcher the teachers carefully discussed the object of learning and questions such as: what does it mean to know about ions, why is it important for students to learn about that specific object, which difficulties and limitations do students usually experience when learning about the object, and which features do students need to identify in order to understand the ion and how ions are formed (i.e. the critical features). In the discussions, the teachers highlighted several concepts they considered as crucial for students' understanding of the object. One such concept was the relationship between the energy level of an electron and its principal quantum number. Another critical feature included the atomic structure and how the ionic charge varies depending on the number of valence electrons. Further, that ionisation energy depends on the number of electrons and that the nucleus with protons and neutrons remains unchanged even though the number of electrons changes. Finally, the students needed to identify the principles of the periodic table and how atoms with one or two valence electrons more or less than a closed shell are highly reactive as the extra electrons are easily removed or gained to form positive or negative ions.

> T2: If we think of ions and atoms, we cannot explain what an ion is without having an understanding of the particles, electrons and protons. The important thing is that they see the differences and relationships between the ion and the other concepts that are critical for understanding this … for example, the atomic structure.

> T1: And really, one cannot talk about this without talking about the periodic table. Why are there ions with minus and plus, what are the differences and the relationships as well? What we can do in the lesson is to show both an ion and an atom to make them notice that both of them have a nucleus of protons and neutrons, both of them have electrons orbiting the nucleus, but the difference between these two is that the number of electrons varies. (Meeting 1)

This discussion emphasised the importance of making students focus on critical features and the *difference* between an atom and an ion instead of only focusing on the ion alone. In terms of PCK development, identifying the object of learning and its critical features offered access to the way in which the teachers conceptualised the topic as a whole and, hence, became an important aspect of articulating the teachers' PCK. When the teachers collectively began to unpack their content knowledge in this way, it helped them develop a clear conceptualisation of the subject area, both for themselves and their students. In so doing, the participants began to think about linking content and pedagogy in new ways that may well be a catalyst for developing PCK.

*To Challenge Students' Ideas and Difficulties within Teaching*

In order to identify students' preconceptions and previous knowledge of the object of learning, the three teachers designed a pre-test consisting of six questions. The test paid attention to the critical features for understanding the object of learning such as the atomic structure, understanding of the periodic table and the difference between a substance and an element. In the analysis of the pre-tests, several issues concerning students' existing understandings were raised. For example, the students did not understand the relationship between an atom and a molecule and did not know about the structure of an atom. Further, the students had difficulties distinguishing the concepts chemical "substance" and chemical "element". Likewise, they had difficulties seeing the connection between the atomic, molecular and elemental structure. The pre-test also indicated that the students had problems understanding how the number of electron shells influenced the atom's reactivity. These difficulties (and ways to approach them within the lesson) were carefully discussed by the three teachers and the researcher. Finding ways to illustrate the difference between elements in the same group, with the same number of valence electrons in their atoms but with different numbers of shells, became an important teaching strategy.

> T1: All substances in group eight have a noble gas structure but if you look at them you see that they have a different number of shells. This is a great opportunity to make the students identify what they have in common and what separates them. They are in the same group and have the same number of valence electrons but they have different numbers of shells. So we can use a demonstration with lithium, sodium and potassium to make the students

see the relationship between periods and groups and introduce the concept of noble gas structure. (Meeting 2)

As such, the co-planning of the lesson helped the teachers develop their ideas on how to challenge the students' identified difficulties and conceptions in a way that should most effectively promote the students' understanding of the object of learning. The teachers came to see that only small variations in their teaching and students ways of discerning critical features of the object of learning made a crucial difference in the students' learning. As such, the result of the pre-test gave the teachers a better insight into aspects of the students' learning they needed to approach in order to teach effectively.

### *To Identify and Analyse Critical Aspects of a Teaching Situation and to Make Qualitative Assessments of Student Learning*

Identifying that which makes it easy or difficult to learn a specific content is a crucial aspect for a teacher's PCK. As such, when analysing the pre-tests the teachers' taken-for-granted assumptions were clearly challenged in a way that forced them to reconsider their planning. In the analysis of the post-test and the first lesson (lesson 1), it was clearly indicated in the students' responses that they still had difficulties distinguishing between an atom and a molecule, a chemical element and an atom but also between an element and a substance. Hence, the teachers realised that they needed to put a stronger emphasis on these aspects and also stimulate the students to identify the difference between the properties of chemical elements in the periodic table. As such, the analysis of lesson one gave the teachers important information on how the students experienced the teaching and what they needed to revise in order to better meet the students' learning needs.

When analysing the video of the second lesson (lesson 2), the teachers noticed that even though they had revised several aspects from lesson one, the second version of the lesson was experienced as much ´busier´ and messier and the results in the post-test were not as the teachers would have expected. The teachers' taken-for-granted assumptions (e.g. that the students understand the atomic structure and the relationship between a chemical element and a substance) was challenged already in the first lesson and the teachers came to understand that the complexity of the content was greater than they had thought in their planning. When the teachers analysed the video from lesson two, they became aware of how many students seemed to believe that the electron shell protects the nucleus of an atom in the same way as a banana peel protects the fruit itself. In their discussions, the teachers highlighted the notion of 'occupied words' as something that seemed to make it difficult to learn a specific concept. Building on the insights from lesson one and lesson two, the third lesson put a stronger focus on the object of learning and teacher three (T3) introduced the lesson with the question "What is the difference between an atom and an ion?". As such, a key insight from analysing the three lessons was about presenting concepts individually or together, to focus on different aspects of the content and not just on one aspect at a time. In their final reflections, the teachers highlighted that small variations in the way they approached the content within their teaching proved to play a crucial role in the students' understanding. They also became aware of the importance to vary the different ways to represent the content (learning object) with various metaphors and experiments, but also to reflect on their use of metaphors and how these can cause confusion if not used correctly.

> T1: I have never thought like this. It is obvious for me what a substance is, but how can I convey this to my students? As a teacher, I think the hardest challenge for us is to transform our own knowledge to students' understanding and to really focus on the object of learning and not a million other things in the same lesson. (Meeting 6)

For example, restructuring the lesson, clarifying differences, similarities and relations between concepts, taking things in a different order or reflecting on their use of concepts in the teaching situations were all features that made a difference in the students' learning. What became clear for the teachers in terms of instructional strategies was that restructuring the lesson, making the abstract concrete, clarifying differences, similarities and relations between concepts but consequently, not presenting too many concepts at the same time, taking things in a different order or reflecting on their use of metaphors and concepts in the teaching situations were all features which created a difference in the students' learning.

## DISCUSSION – LEARNING FROM THE LEARNING STUDY

> What is it that a teacher knows and is able to do that a specialist in the subject matter that that teacher is teaching, no matter how smart they are, doesn't understand and can't do? (Shulman, quoted in Berry, Loughran, & Van Driel, 2008, p. 1275)

This study pays attention to this question by focusing directly on how teachers handle and organise the content in order to promote students' learning. Recently, in their argumentation on teacher professional development focusing on PCK Van Driel and Berry (2012) stressed the importance of "forms of professional development for teachers that are built on collaboration, collegial interaction and the fostering of relationships" (p. 26). This study is an example of such an approach to understand teacher professional learning through a careful investigation of how teachers' professional knowledge of teaching (PCK) is enhanced by their participation in a learning study and, further, how students' learning might be developed as a consequence. It points to the particular role of research-based learning in providing an opportunity for teacher learning as a metacognitive lens through which to view the task of science teaching in the secondary classroom. The study indicates that the teachers' participation in the learning study proved to be helpful in their (re) considerations of their science teaching. It also challenges the taken-for-granted assumption that 'if you teach – students learn'. Research about the effects of a learning study supports the conjecture that the students' learning increases from lesson one to lesson three (see e.g., Marton & Pang, 2006; Runesson, 2006, 2008). However, an important aspect of this study is that, for lesson two, the students' results decreased, something that forced the teachers to reconsider their taken-for-granted assumptions and pedagogical decisions. Further, as Nuthall (2005) noted, teachers commonly attribute failure in student learning to the students' lack of ability or motivation, rather than to their own teaching. Participation in a learning study challenges this view as the focus is moved from more general aspects of pedagogy to content-specific aspects of teaching and learning. The study contributes to the teaching and learning of science as it points to the particular role of research-based learning in providing an opportunity for 'learning practice' as a metacognitive lens through which to view the task of science teaching in the secondary classroom. During the learning study process, the teachers developed their self-understanding in which they questioned their own epistemological beliefs, aims and objectives of teaching and taken-for-granted assumptions about science teaching and learning. An important implication of this project is the importance of teacher professional learning as a collective process in which teachers and researcher(s) together explore students' learning in relation to science teaching.

The message inherent in this project is the potential to positively focus on teacher collaboration in developing science teachers' professional learning in ways they personally value. Therefore, an important consequential activity is the ability to develop a framework of quality in-service science teaching that builds on the ways in which, through collaboration and reflection, teachers play an active role in understanding and developing their PCK. This project highlights that participating in a learning study is an important vehicle for supporting science teachers' competence in teaching as it allows them to identify strengths and weaknesses in a continuous, non-threatening way. By stimulating teachers to research their own practice, teachers are helped to identify the complexity of teaching and further become aware of what they need to do to improve their teaching and learning practices.

Shulman (1987) noted that developing PCK involves a considerable shift in teachers' understanding "from being able to comprehend subject matter for themselves, to becoming able to elucidate subject matter in new ways, reorganize and partition it, clothe it in activities and emotions, in metaphors and exercises, and in examples and demonstrations, so that it can be grasped by students" (p. 13). Twenty-five years later, Hattie (2012) noted that great power emerges from teachers learning from each other and talking together about planning, learning intentions, learning progressions and success criteria. Collegial reflections about what makes a difference in students' learning leads to important debates about evidence of students' learning and the quality of teaching. When teachers begin to collaborate and develop common understandings, particularly a common understanding of what makes a difference in their students' learning processes, then they all begin to move in the *right* direction based on collaborative reflections, shared practices and multiple interactions. What became evident in this study is that there are several ways to engage teachers in collaborative discussions about student progression. The result presented in this study supports the idea that teachers do not simply receive knowledge that others create to teach, but produce knowledge for teaching through their own experiences. What is important is that teachers are open to looking at evidence of their impact on students' learning and providing a critical analysis of each other's practices to better meet the needs of the students.

With its focus on collegial planning and reflection through the learning study design, this study also corresponds with the ideas of Van Driel and Berry (2012) who highlighted the importance of "forms of professional development for teachers that are built on collaboration, collegial interaction and the fostering of relationships" (p. 26). Therefore, the learning study can be described as both a research method and a successful model for the continuous professional learning of teachers.

When the teachers collectively began to unpack their content knowledge in this way (i.e. through identifying critical features), it helped them develop a clear conceptualisation of the subject area in terms of the students' understandings, their own subject understanding and their instructional strategies. In doing so, the possibility emerges that the participants may begin to think about linking content and pedagogy in new ways, something that may well be a catalyst for developing their PCK. The teachers also stressed that their joint planning and collegial reflection was central to their own learning process. The findings further indicate that the use of a learning study as a research method encourages teachers to begin to embrace PCK in their own practice. This research process therefore offers a number of interesting learning outcomes. The first is that of the research design and associated outcomes through the use of learning study methodology. The second is the manner in which, through involvement in the research itself, teachers are supported and empowered in their learning about science teaching.

As Loughran (2006) noted, "professional learning is not developed through simply gaining more knowledge, rather, professional learning is enhanced by one becoming more perceptive to the complexities, possibilities and nuances of teaching contexts" (p. 136). As such, real possibilities for meaningful approaches to knowledge growth and practice emerge as recognition of the necessary primacy of professionals' knowledge. In such a way, a learning study responds to teachers' professional needs and concerns with regard to teachers' engagement, ownership and decision-making within their classrooms.

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