Examining science teachers' pedagogical content knowledge in the context of a professional development program

Wongsopawiro, D.S.

Chapter 1. General introduction

1.1. Introduction

Teachers are the most important factor in student learning (National Research Council, 1996). They determine what is taught in the classroom and how it is taught, making them a critical factor in students' learning (Abell, 2007; King & Newman, 2000). In early days, research on science education focused on science teachers who needed to be well-qualified and passionate in their field of expertise. Over the years, however, it became evident that the possession of expert content knowledge was no guarantee of 'good science teaching'. Science teachers should not only have good subject matter knowledge (SMK), but should also possess pedagogical knowledge (PK). Successful science teachers should get students engaged to help them understand the natural world, to apply scientific principles, and consider careers in the sciences (NRC, 1996). Research in science education has determined that successful science teachers must have strong subject matter knowledge, a good understanding of the nature of science, and be able to translate scientific concepts into meaningful learning experiences for their students (Feiman-Nemser, 2001; Gess-Newsome, 1999b). Recent studies have claimed that science teachers should have a deep understanding of scientific concepts, knowledge of students as learners, knowledge of instructional strategies, knowledge of assessment strategies, and knowledge of curricular resources, thus placing teachers' knowledge at the heart of science education research (Darling-Hammond, 2008). The process of learning to teach means learning how to systematically organize knowledge so that it can be drawn upon and applied to new situations (Berliner, 2001). To understand the knowledge that is needed for science teaching, Shulman (1986, 1987) introduced the concept of pedagogical content knowledge (PCK) as a unique form of knowledge for teaching that makes a content domain understandable for learners. Effective teachers need to develop knowledge with respect to all of the aspects of pedagogical content knowledge and with respect to all of the topics they teach (Magnusson, Krajcik, & Borko, 1999, p. 115). To understand science teaching, it is of pivotal importance to investigate the nature of the PCK of in-service science teachers and how that knowledge guides their teaching: 'A real and serious issue in teaching is the ability to capture, portray, and share knowledge of practice in ways that are articulable and meaningful to others' (Loughran, Berry & Mulhall, 2006, p. 15). A deeper understanding of the nature of the PCK of in-service science teachers provides important insight for science teacher educators as they design their programs for student-teachers (Abell, 2008). Barnett and Hodson (2001) noted that teaching remains a complex enterprise where teachers continually need to adjust their instructional strategies to ensure student learning. Explicating teachers' professional knowledge in the form of pedagogical content knowledge, and sharing it with colleagues or student-teachers, could be the main key to effective professional development of in-service science teachers (cf. Wallace & Louden, 1992). A model of successful teaching practice could inform teachers' professional development (PD) programs. The development of such models can be achieved by carefully investigating and analyzing the practice of in-service teachers (Barnett & Hodson, 2001; NRC, 1997). In this thesis we investigated the pedagogical content knowledge of experienced in-service science teachers in a professional development setting. In this specific context we followed in-service teachers who designed and taught lessons to improve their teaching. We were able to investigate how in-service teachers drew upon their pedagogical content knowledge to plan and conduct their lessons. In this program teachers used an action research approach to improve their teaching. With the use of this approach, we were also able to investigate how their PCK developed as a result of participating in a PD program that aimed to improve their teaching. Investigating what the PCK is that teachers draw upon and how this PCK develops could help us to understand how this particular form of knowledge is actually used in classroom settings.

Understanding the nature of teacher pedagogical content knowledge and how its components are drawn upon when teaching can be accomplished through an investigation of in-service teachers (Berliner, 1986; Shulman, 1986). In this thesis, we investigated how PCK components were used and developed as in-service teachers participated in the professional development program aimed at improving classroom teaching. Investigating in-service teachers' pedagogical content knowledge allowed us to deepen our understanding of what 'good science teaching' is and how it may actually occur in a classroom setting. Our investigations also informed us how we could develop research on teacher knowledge more vigorously.

1.2. Teacher knowledge

Teachers' knowledge and beliefs give meaningful consistency to experiences, thoughts, feelings and actions within a certain context (Posner, Strike, Hewson, & Gertzog, 1982). Feiman-Nemser (2001) notes that teacher knowledge develops as teachers learn to make concepts understandable to their students. Teacher knowledge is closely related to individual experiences and contexts and, therefore, unique and practical to the individual teacher (Verloop, Van Driel, & Meijer, 2001). Teachers' practical knowledge includes the teachers' knowledge about the content, their beliefs about their own teaching practice, and their teaching experience (Van Driel, Beijaard, & Verloop, 2001). The development of the knowledge is a process where teachers try new ideas, refine old ones, and engage in classroom problem-solving (Wallace, 2003). Through experience, teachers develop a knowledge that regulates their own teaching (Carter, 1990). Teacher practical knowledge has been researched and described in numerous research studies (Abell, 2007; Doyle, 1985; Grossman, 1989; Lee, Brown, Luft, & Roehrig, 2007; Lee & Luft, 2006; Magnusson et al. 1999; Meijer, 1999; Van Driel, Verloop, & de Vos, 1998), yet little evidence has been found to determine how this knowledge actually guides decisions in classroom teaching (Calderhead 1996; Black & Halliwell, 2000). There is general agreement, however, that teachers' practical knowledge guides their actions in the classroom (Lantz & Kass, 1987, Verloop, 1992). Van Driel et al. (2001) argue that the concept of practical knowledge 'refers to the integrated set of knowledge, conceptions, beliefs, and values teachers develop in the context of the teaching situation'(p. 141). Teachers' practical knowledge is action-oriented (Beijaard & Verloop, 1996) and person- and context-bound (Johnston, 1992; Stigler, Gallimore, & Hiebert, 2000). It includes tacit and integrated knowledge (Beijaard & Verloop, 1996). In discussing the concept of PCK, Shulman (1987) noted that successful teachers are able to transform their knowledge of scientific concepts into a form of knowledge that can be understood by learners, by integrating their knowledge of learners, representations, instructional strategies, assessments, and curricular resources to create meaningful learning opportunities that make connections between lesson content and students' experiences.

1.2.1. Pedagogical content knowledge

PCK is a central component of the teachers' practical knowledge and is based on both subject matter knowledge and pedagogical knowledge (Van Driel et al., 1998, 2001; Van Driel, De Jong, & Verloop, 2002). Teaching experience also influences the development of PCK (Clermont, Borko, & Krajcik, 1994). Shulman (1986, 1987) expressed the need for a theoretical formulation to identify the different components of teachers' teaching capabilities, as well as the conditions for developing them. He classified teachers' knowledge into content knowledge (subject matter knowledge), pedagogical knowledge, and pedagogical content knowledge. Pedagogical content knowledge was introduced as a concept that represents the kind of knowledge that teachers use in their classroom teaching. Thus 'understanding the development of teachers' subject matter knowledge and PCK is critical for our success in science teacher education' (Abell, 2007, p. 1133).

Lee Shulman (1986, 1987) described PCK as a unique form of knowledge for teaching which is based on subject matter knowledge, knowledge of potential student learning difficulties, and students' prior knowledge of specific concepts, as well as the most effective models, analogies, illustrations, explanations, and investigations to make the concept understandable for students. In his work Lee Shulman explained that PCK conceptualizes 'the ways of representing and formulating that subject that makes it comprehensible to others'(Shulman, 1986, p. 9). In 1987, Shulman rephrased his definition of pedagogical content knowledge as a 'special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding' (p. 8). In his understanding, teachers use both their content knowledge and their pedagogical knowledge in a blended way to promote student learning. Although Shulman's view has been widely used, many scholars have interpreted it in different ways resulting in different PCK models over the years (Grossman, 1990; Marks, 1990; Magnusson et al., 1999; Hashweh, 2005; Fernández-Balboa & Stiehl, 1995; Koballa, 1999; Cochran, DeRuiter, & King, 1993, Kind, 2009).

For the purpose of this study, we selected a model of PCK for our research. Magnusson et al. (1999) proposed a PCK model, which has been widely used to understand science teaching. After Schulman (1987) and later Grossman (1990), they posited that in order to teach a certain content, several types of knowledge (including subject matter knowledge) are transformed into the pedagogical content knowledge suitable for teaching. The Magnusson et al. (1999) PCK model has been discussed by other scholars (Abell, 2007, 2008; Kind, 2009; Friedrichsen & Dana, 2005). Some scholars have used the PCK components derived from the Magnusson et al. model in their studies (Henze, Van Driel, & Verloop, 2008; Kaya, 2009; Justi & Van Driel, 2006; De Jong & Van Driel, 2004). In their review studies, Abell (2007) and Kind

(2009) explained that this model is useful for studying the PCK of science teachers. In the following section, we briefly outline this PCK model which we used for our study.

1.2.2. Magnusson et al. (1999) model of PCK

Magnusson et al. (1999), who described PCK as 'the transformation of several types of knowledge for teaching' (p. 95), proposed a model to study science teachers' pedagogical content knowledge. This model is derived from earlier models proposed by Shulman (1986) and Grossman (1990). Magnusson et al. (1999) defined five components of PCK: (1) orientations toward science teaching; (2) knowledge and beliefs about science curriculum; (3) knowledge

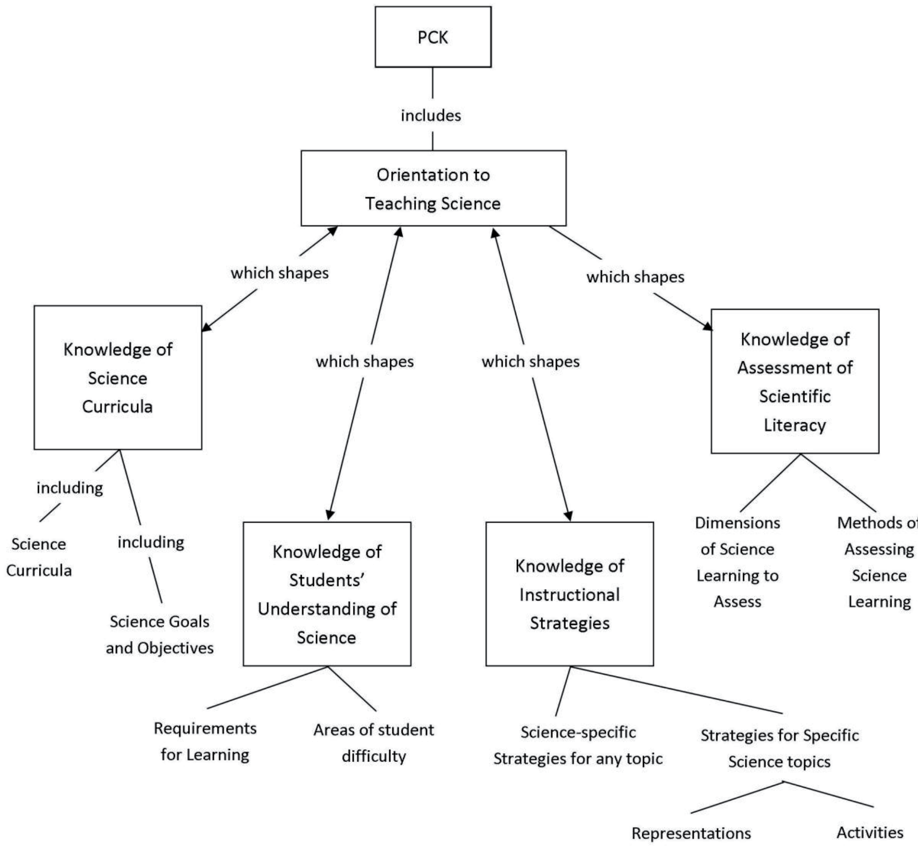

Figure 1.1. PCK model for science teaching (Magnusson et al., 1999, p. 99).

and beliefs about students' understanding of specific science topics; (4) knowledge and beliefs about assessment in science; and (5) knowledge and beliefs about instructional strategies for teaching science (p. 97). Magnusson et al. (1999) explained that the orientations of science teaching serve as a map that guides other PCK components (see Figure 1.1).

We explain the PCK components from the Magnusson et al. (1999) model using other literature for each component:
(1) *Orientation toward teaching science[1]:* Magnusson et al. (1999) described the orientation to science teaching as 'the knowledge and beliefs possessed by teachers about the purposes and goals of teaching science at a particular grade level' (p. 97). They then expanded that by saying 'the orientations are generally organized according to the emphasis of instruction' (p. 97). Teaching orientations act as 'conceptual maps' guiding the decisions about learning objectives, implementation of curricular materials, and evaluation of students' learning (Magnusson et al. 1999, p. 97). Some scholars have argued that the orientations towards teaching science have not been studied well (Friedrichsen & Dana, 2003, 2005; Friedrichsen, Van Driel, & Abell, 2011; Talanquer, Novodvorksy, & Tomanek, 2010). Friedrichsen and Dana (2005) explained that studying orientations can be complicated since teachers hold multiple goals when teaching. They also noted that teaching orientations are still a 'messy concept'. Some scholars used other terms such as 'preconceptions of teaching' (Weinstein, 1989;1990), 'approaches to teaching' (Trigwell, Prosser, & Taylor, 1994), or 'conceptions of teaching' (Hewson & Hewson, 1987; Hewson, Kerby, & Cook, 1995; Lemberger, Hewson, & Park, 1999; Lyons, Freitag, & Hewson, 1997; Meyer, Tabachnick, Hewson, Lemberger, & Park, 1999) to study teaching orientations.

(2) *Knowledge of science curricula:* This type of knowledge refers to the teacher's understanding of the goals and objectives for student learning

1 Orientation toward teaching science is sometimes referred to as 'orientations to teaching', 'science teaching orientation' or 'teaching orientation' in the text.

and the scope and sequence of the scientific concepts. Knowledge of science curriculum consists of two categories: (a) knowledge of goals and objectives; and (b) knowledge of specific curricular programs (Magnusson et al. 1999, p. 103). Abell (2007) argued that most curricular studies have not focused on teachers' knowledge of the curriculum, but rather focused on teachers' ranking of the importance of science goals (p. 1129). Some studies have focused on inquiry-oriented curricula. Jones and Eick (2007) studied changes in teachers' PCK when they introduced an inquiry-oriented curricular program. Some studies have argued that more research is needed to understand how teachers' knowledge of the curriculum is being used in practice (Furio, Vilches, Guisasola, & Romo, 2002; Jones & Eick, 2007; Kesidou & Roseman, 2002; Schneider & Krajcik, 2000).

(3) *Knowledge of students' understanding of science:* This PCK component includes: (a) knowledge of the requirements for learning which refers to the prerequisite knowledge for learning specific scientific knowledge; and (b) knowledge of areas of student difficulty which refers to knowledge of those science concepts that students find difficult to learn (Magnusson et al., 1999, p 105). In her handbook chapter, Abell (2007) found that studies focused on teachers' knowledge of student understanding reported general views of teaching (p. 1127). Halim and Meerah (2002) found that teachers were unaware of students' misconceptions and had inadequate subject matter knowledge. De Jong and Van Driel (1999) found that more teachers were becoming aware of the students' learning difficulties after they reflected on their lessons. Abell (2007) noted that, overall, teachers lack knowledge of students' conceptions, but that this knowledge improves when teachers gain more experience.

(4) *Knowledge of assessment:* This component of PCK consists of two subcomponents: (a) 'knowledge of the dimensions of science learning to assess' which refers to knowledge of aspects of students' learning that are important to assess within a particular unit or lesson; and (b) 'knowledge

of methods of assessment' which refers to knowledge of ways to assess those specific aspects of students' learning. The knowledge of methods of assessment includes knowledge of specific instruments, procedures, approaches or activities that can be used during the assessment.

(5) *Knowledge of instructional strategies*: This component has two kinds of knowledge: (a) knowledge of subject-specific strategies refers to the ability to use general teaching approaches in broad applications; and (b) knowledge of topic-specific strategies includes ways to represent concepts and engage students with instructional strategies to facilitate student learning of specific concepts in science (Magnusson et al. 1999).

Many other scholars have used this model to study the development of the PCK of science teachers who taught a particular topic (Henze et al., 2008; De Jong, Van Driel, & Verloop, 2005; Lankford, 2010). Both Abell (2007) and Kind (2009) noted in their review studies that the Magnusson et al. (1999) PCK model seems to encompass what is needed in science education and is most useful for research on teachers' knowledge. Science education research based on this model can further our understanding of how teachers draw upon their knowledge and beliefs to teach effectively. Many questions still remain that need to be investigated. Questions remain such as: How is an orientation actually linked to the other PCK components? How can the PCK of science teachers be typified in a professional development setting? How do the specific PCK components develop? or How are the components linked to the teachers' practice? More research is needed to deepen our understanding of PCK. Many studies have focused on the PCK of pre-service teachers in a teacher training program, however, few studies have used professional development programs as a specific context where the PCK development of in-service teachers is investigated and monitored. This thesis reports on four studies aimed at improving our understanding of pedagogical content knowledge in practice using the Magnusson et al. (1999) PCK model. In particular, we examine the different components when teachers are participating in a PD program to improve their teaching using classroom action research as a vehicle to reach their goals.

1.2.3. Professional development programs

Professional development plays an essential role in the improvement of student learning (Desimone, 2009). Many professional development programs equip teachers with new activities to be implemented in their classrooms. However, many of these programs have proven to be unsuccessful for a variety of possible reasons. First, the traditional top-down approach encourages teachers to be passive participants exposed to new ideas of 'learning experts'. This has been unsuccessful because it fails to take teachers' practical knowledge into account (Van Driel et al., 2001; Haney, Czerniak, & Lumpe, 1996; Klinger, 2000). Second, teachers do not implement the suggested strategies according to the intentions of the learning experts (Wallace & Louden, 1992). PD developers often neglect to take the teachers' practical knowledge into consideration when planning and developing their program . This practical knowledge includes the content knowledge, pedagogical knowledge, and beliefs of practising teachers. Teachers' practical knowledge has a major influence on the way they respond to professional development programs (Verloop, 1992). Specifically, professional development programs that focus on students' learning often deepen teacher's content knowledge and their knowledge of ways to transfer this knowledge to students (Cohen & Hill, 2000; Kennedy, 1999; Wiley & Yoon, 1995). Successful professional development programs offer effective strategies assisting teachers to promote students' learning. One of the principles of an effective math and science professional development program is to encourage in-depth understanding of core concepts, instead of minimal breadth coverage of the topic. Through an in-service PD program, teachers might deepen their own understanding of content knowledge and learning to transfer their knowledge to their students. To serve students' learning, teachers transform their own content knowledge developing several components of pedagogical content knowledge. PCK development is a product of planning, teaching, and reflecting.

Professional development programs are often used by reform-minded teachers as an opportunity to find novel ways of addressing content. Some scholars have cautioned that educational reform should not only focus on teachers' content knowledge, but should also consider the cognitions, beliefs, and attitudes of the participants (Haney et al., 1996). Most PD programs do not take specific classroom problems into consideration, nor do they focus on the teacher's individual interest in gaining new knowledge and skills. The failure to take teachers' own interests into consideration dooms the PD programs to fail. The focus of a PD program should be on teachers' learning (Ball & Cohen, 1999). Recently, professional development programs have not only focused on the teachers' content knowledge, but incorporated their pedagogical growth as well (Bell, 1998). Some PD programs focus on specific content knowledge instead of general knowledge, or a specific way of teaching a certain topic. In the PD model of Bell and Gilbert (1996), the teachers were encouraged to take students' gaps in knowledge into consideration. In the last decade several studies have been published on effective professional development, teacher learning, and teacher change (Carey & Frechtling, 1997; Cohen & Hill, 1998; Loucks-Horsley, Love, Styles, Mundry, & Hewson, 2003; Richardson & Placier, 2002). In a professional development setting, teachers reflect on their personal practical knowledge. Some research has focused specifically on the effects of professional development on improving teachers' content knowledge (Van Driel et al., 2001). Several PD programs have been studied to learn about the use of pedagogical content knowledge and the change in teachers' beliefs (Bell & Gilbert, 1996; NRC, 1996, Lumpe, Haney, & Czerniak, 2000).

1.2.4. Teachers' professional development

To understand teachers' professional development it is necessary to understand the underlying learning processes and the conditions that support teachers' learning (Clarke & Hollingsworth, 2002). To understand these processes, researchers should identify when, where, and how this learning occurs. Models for teachers' professional development can focus on these processes and are extremely helpful in research. Different models of teachers' professional development have been proposed over the years. While some solely focused on teachers' learning outcomes, others also took the learning processes into account. Professional development models have played an important role in changing teachers' knowledge aiming at improving student learning outcomes (Abell, 2007). Guskey (1986, 2002b) proposed a linear model of teacher change, assuming that a professional development program causes changes in a teacher's practice, which in turn leads to changes in students' learning and therefore results in changes in teachers' knowledge, beliefs, and attitude after reflection (see Figure 1.2: Guskey's model of change, 1986).

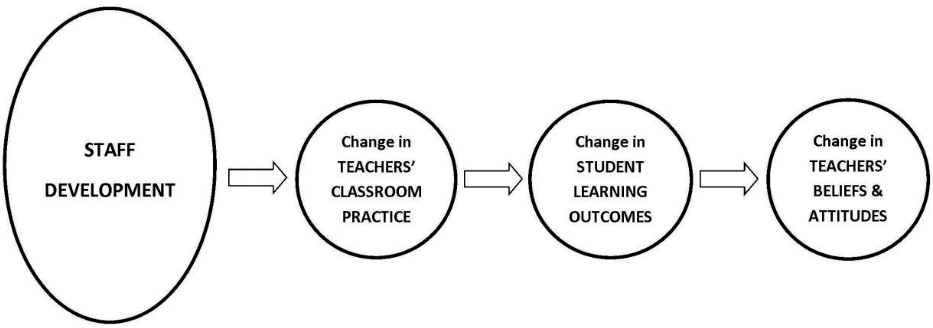

Figure 1.2. A Model of Teacher Change (Guskey, 1986, p. 7)

Other researchers, however, pointed out that teacher learning is not a linear process, but a complexity of processes where teachers are engaged in active and meaningful learning. Sprinthall, Reiman, and Thies-Sprinthall (1996) proposed a non-linear interactive model and argued that there is a close relationship between changes that occur in students' scientific conceptions and changes occurring in the conception of the teacher. Furthermore, changes in the way a teacher teaches also involves a conceptual change in the teacher's pedagogical knowledge (Posner et al., 1982). Although a number of studies have focused on the professional development of teachers, the individual professional development processes have not been studied extensively (Hashweh, 2003; Zwart, 2007). Clarke and Hollingsworth (2002) provided an interconnected model of teachers' professional growth (IMTPG), where changes in teachers' knowledge are seen as a result of active and meaningful learning. *'Teacher growth becomes a process of the construction of a variety of knowledge types (content knowledge, pedagogical knowledge, and pedagogical content knowledge) by individual teachers in response to their participation in the experiences provided by the professional development program and through their participation in the classroom'* (Clarke & Hollingsworth, 2002, p. 955). In this thesis, we define teacher learning as both a change in teachers' cognition (e.g., knowledge and beliefs) and their behaviour (cf. Zwart, Wubbels, Bergen, & Bolhuis, 2007).

The Clarke and Hollingsworth model (2002) describes domains which are not identical to Guskey's linear model (1986), but it incorporates the complexity of the process of teachers' professional growth. This non-linear model can be used as both an analytical and a predictive tool. It can also provide a theoretical background, for example by using the various domains in designing professional development programs. This model has been used as an analytical tool to study teachers' learning in secondary schools (Justi & Van Driel, 2006; Zwart et al., 2007). In the present study we used this model to measure teachers' growth. We studied how each of the PCK components changed when in-service teachers devoted time and effort to preparing, implementing, and reflecting on their teaching of science. The IMTPG was proposed by Clarke and Hollingsworth (2002) to investigate changes in four different domains. Underpinned by empirical data, the authors established four different domains: (1) the Personal Domain, which includes the teacher's knowledge, beliefs, and attitudes; (2) the External

Domain including external resources, information, or stimuli; (3) the Domain of Practice involving professional experimentation; and (4) the Domain of Consequence including salient outcomes such as students' motivation, changes in students' behaviour, or students' developing new ideas. The authors found evidence that a change in one domain causes changes in other domains. Through processes of enactment and reflection, the model suggests possible pathways for change resulting in growth networks, which in turn represent the professional growth of a teacher (see Figure 1.3). An enactment is a specific action of a teacher based on a certain belief or knowledge, such as providing students with microscopes to study the structure of cells. Reflection is seen as 'active careful consideration' (Clarke & Hollingsworth, 2002, p. 954) such as reflecting on a classroom experiment.

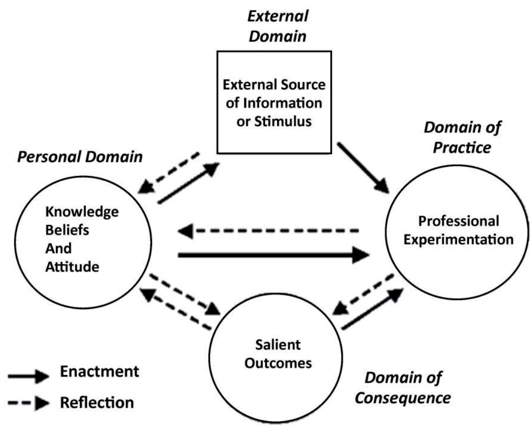

Figure 1.3. The Interconnected Model of Teacher Professional Growth (Clarke & Hollingsworth, 2002, p. 951).

1.3. The context of the study

This study was conducted within a professional development program for in-service teachers called the Mathematics and Science Partnerships program (MSP program). With support of the National Science Foundation, this partnerships program was designed to educate and support K-12 mathematics and science teachers. The MSP is a program for the different states of America; each state administers its own program, monitors progress, and documents its effectiveness, while working with the U.S. Department of Education. All MSP projects are funded by the states and report to the federal government on an annual basis. The MSP program is focused on teacher knowledge and student learning. The Mathematics and Science Partnerships program aims to improve teacher quality. The intent of the program is to increase the academic achievement of students in mathematics and science by enhancing the content knowledge and teaching skills of classroom teachers. The goals of this three-year grant-aided program were threefold: (1) to increase teachers' content knowledge; (2) to increase teachers' pedagogical (content) knowledge; and (3) to increase the teachers' use of action research. Each year a cohort of mathematics and science teachers participated in professional development activities. The partners in this particular project included the Regional offices of Education (ROE), local universities, school districts, and teachers in Southern Illinois.

1.3.1. The MSP program

During one year teachers were encouraged to conduct an action research project within their own classroom. This program started each year with a two week summer workshop called the summer institute. During the first week of the workshop, the teachers were taught how to conduct action research in the classroom. In that first week the teachers also attended mathematics and science presentations from university staff concerning 'best practices in school'. At the end of the first week the teachers had to choose a science or a math topic to focus their action research on. In the second week the teachers were able to study the literature about their topic, to study 'best practices' about teaching that topic, and to work out an action research plan. After those two weeks the teachers were asked to plan lessons based on their action research plan. In the following year, the teachers had to conduct their action research in the classroom. During that year, they met with the academic staff who functioned as their mentors and their critical friends (Ponte, Ax, Beijaard, & Wubbels, 2004). The teachers kept a progress report, an online reflective journal, and collected students' artifacts throughout the year. At the end of the year they turned in their progress report, including the lesson plans, and their students' artifacts. Some teachers took part in an interview after completing their action research. This study included three cohorts of teachers from three consecutive years.

1.4. Design and focus of the study

To study the pedagogical content knowledge of in-service teachers, we used both quantitative and qualitative approaches to study the different components of PCK. The main question of this thesis is: *What is the pedagogical content knowledge of science teachers when they prepare and conduct lessons as part of a specific professional development program to improve their science teaching and how does this PCK change when they participate in a PD program?*

To answer this question, we devised four research questions:

1. What are the orientations of science and mathematics teachers to teaching science or math in the context of a professional development program?
2. How can in-service science teachers' pedagogical content knowledge be typified at the end of a professional development program to improve their teaching?
3. What are the possible pathways that lead to changes in science teachers' pedagogical content knowledge in a professional development program?
4. What is the relation between the teachers' concerns, their orientations towards science teaching, and the inquiry-based instructional levels of inquiry when they design and conduct lessons?

Four studies were conducted using both quantitative and qualitative approaches to answer these research questions.

1.5. Relevance of the study

Research on PCK has long been the focus of numerous science scholars. Over the years many models of PCK have been introduced and used in both research and teacher education programs. We tried to contribute to this research by investigating what PCK looks like when teachers engage in a professional development program. In the last three decades, researchers have proposed PCK models with distinct components in each model. The Magnusson et al. (1999) model has often been used as a model to investigate pre-service teachers' PCK. Understanding PCK can lead to understanding what 'good science teaching' is all about and how we can foster teacher education programs which focus on developing PCK of pre-service science teachers.

1.6. Outline of the study

In the first study (aimed at the first research question; see Chapter 2) we investigated the orientations of 107 in-service science and mathematics teachers. Orientations towards teaching are seen as an overarching conceptual map that 'shapes' the other PCK components and are therefore pivotal in PCK research (Magnusson et al., 1999). Understanding these orientations can actually broaden our understanding of how teaching orientations influence other PCK components and the teachers' practice. Using triangulation of the teachers' action research plans, their lesson plans, and their reflective journal, we compiled data from three different sources to investigate this phenomenon. In this study we used a mixed-method approach to identify the various orientations and to describe these orientations. Using hierarchical cluster analyses (HCA) and principal component analyses (PCA) we tried to determine the teachers' orientations when they engage in the planning and implementation of an action research project in their own classroom.

In the second study (aimed at the second research question; see Chapter 3), we investigated the relations between the different PCK components, using the teachers' concerns and the purposes of teaching, when the teachers prepared and conducted improved lessons. In this study we used the teachers' interviews together with their action research progress reports to collect data. Using a qualitative approach we determined how teachers' concerns, teaching purposes, and the different PCK components were related to one another.

In the third study (aimed at the third research question; see Chapter 4) we investigated how the PCK components changed when the teachers engaged in action research. We triangulated the teachers' interviews, their progress reports and their reflective journals to determine the changes in their PCK. Using the interconnected model of teachers' professional growth (Clarke & Hollingsworth, 2002) we investigated how each of the knowledge components changed through processes of enactment and reflection.

In the fourth study (aimed at the fourth research question; see Chapter 5) we investigated the content of PCK in relation to inquiry-based teaching. We investigated the inquiry-based levels of instructions of science teachers in relation to their concerns, and their teaching orientation when planning and conducting inquiry-based instructions in their lessons. Teachers' progress reports, their lesson plans, and their reflective journals were used as data sources for this study. We used the model of Bell, Smetana, and Binns (2005) to determine the level of inquiry of 24 science teachers. To understand what kind of inquiry and why these teachers use inquiry to teach certain science topics, we investigated what orientations and concerns these teachers have when teaching science as inquiry.

In Chapter 6 we try to answer the main research question. We discuss the findings of the four studies in order to answer how the PCK components were related and how they changed. Finally we discuss all the findings and we make some recommendations for future research. In this chapter we also discuss the robustness of the model of Magnusson et al. (1999). For each study we used different cohorts of the MSP program. For the first study, we used all the participants of three cohorts. For the second and the third study, we used twelve science teachers from the first and the second cohort, and for the fourth study we used the third cohort of the MSP program (see Figure 1.4). We selected different data sources to answer the specific research questions of each study.

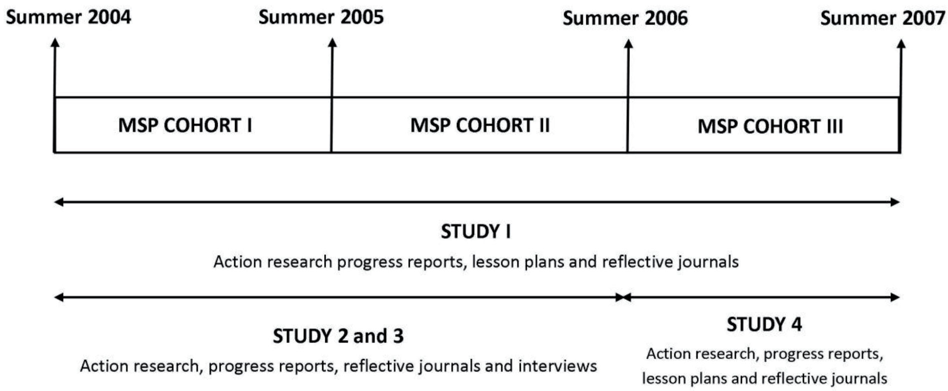

Figure 1.4. Outline of the studies in three cohorts