



Universiteit
Leiden

The Netherlands

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

Wongsopawiro, D.S.

Citation

Wongsopawiro, D. S. (2012, January 24). *Examining science teachers' pedagogical content knowledge in the context of a professional development program*. *ICLON PhD Dissertation Series*. Retrieved from <https://hdl.handle.net/1887/18396>

Version: Corrected Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/18396>

Note: To cite this publication please use the final published version (if applicable).

Chapter 6. General conclusions and discussion

6.1. Introduction

The aim of this research was to examine the pedagogical content knowledge of science teachers who prepared and conducted lessons to improve their teaching. The research was conducted in the context of a professional development program aimed at improving science and mathematics teaching. Examining science teachers' PCK is a complex task (Abell, 2007). Our main question was: *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 used the PCK model of Magnusson et al. (1999). Magnusson et al. (1999) defined five components of PCK: (1) orientations toward science teaching; (2) knowledge and beliefs about science curriculum; (3) knowledge 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). This model illustrates how various knowledge components are related to one another in the PCK framework (see Chapter 1). Using this model, we investigated the teachers' orientations towards teaching (Chapter 2), as well as how the PCK components related to one another in different types of PCK (Chapter 3). We also studied how these components changed as teachers participated in a PD program (Chapter 4) and we investigated how the orientations were related

to the science teachers' practices when conducting inquiry-based lessons (Chapter 5).

To answer the main question, we conducted four studies with the following 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 instructional levels of inquiry when they design and conduct lessons?

6.2. General conclusions of the studies

6.2.1. Study I

In the first study we aimed to identify teaching orientations of mathematics and science teachers. We investigated 107 science and math teachers who participated in three cohorts of the mathematics and science partnership program, where they conducted an action research project to improve their teaching of math or science. We used their action research plans to determine the teachers' orientations. We found that although math and science teachers held specific teaching orientations, these orientations could be categorized in three main orientations: content-driven orientations with teacher-oriented activities, content-driven orientations with student-oriented activities, and skills-driven orientations with student-oriented activities. Teachers who were content and teacher-centered, wanted their students to gain a better understanding of math or science. They intended to

use traditional approaches such as classroom lecture combined with some hands-on activities. Another group of teachers was also content-driven, but intended to use student-oriented activities. They wanted their students to gain a deep understanding of math or science using other types of activities, such as experiments, projects, and laboratory work. The third group of teachers was skills-oriented. They wanted their students to be able to do science or do mathematics. They intended to use classroom investigations or projects to have the students learn how to do science or mathematics. We found that the Hodson goals (1992) were very useful in describing these orientations. The Hodson goals include the learning of science (or math) content, the learning of skills and learning about science (or math). In this study, we found that some teachers had an additional goal: liking science or mathematics. This goal represented the increase in students' motivation or the development of a positive attitude to learning science or math. We found that motivation was a goal found in all three orientation types (see Table 6.1)

Table 6.1.

Three main orientations with different goals and intended strategies

Orientation to teaching	Main goals	Intended instructional methods
Content-driven with teacher-centered approaches	Increase students' content knowledge	Lecture, hands-on activities
Content-driven with student-centered approaches	Increase students' content knowledge and skills	Experiments, hands-on activities, laboratory work
Skills-driven with student-centered approaches	Increase students' skills	Projects, experiments, classroom investigations

We concluded from this study that the orientations played an important part in teachers' PCK. Although we found that the orientations towards teaching could be categorized in three main orientations, we concluded that these orientations were influenced by multiple goals, which made the orientations rather unique to each individual teacher. The goals were often

influenced by the teachers' individual concerns, making it important to have teachers reflect on past experiences as their concerns were to a large extent determined by their past experiences. We also concluded that motivating students to make them interested in science or math was an important goal which was found in all orientations. Teachers were concerned that students were not motivated to learn science and therefore did not succeed in their endeavors. We concluded that the orientations towards science or mathematics teaching were mostly determined by the goals, the teachers' concerns, and their intended instructional strategies .

6.2.2. Study II

To answer the second research question we selected twelve science teachers, investigated their action research reports and conducted interviews with them. From their plans and their responses to the interview, we found three types of PCK, which were primarily driven by the teachers' concerns and purposes for teaching. The first type of PCK was characterized by teaching science skills. Teachers with this type of PCK started their action reports worrying about their students not being able to do science. The second type was focused on teaching content. We found that teachers with PCK type II were concerned about their students' low test scores. The third PCK type was focused on motivating students to learn science and to learn about science. The teachers with this type of PCK found that their students were bored with science and wanted them to get excited about learning and doing science (see Table 6.2).

Table 6.2.

Three types of non-topic-specific PCK.

PCK TYPE	Concerns	Science teaching purpose
I. Knowledge of teaching science process skills	Students have poor lab skills Students need to develop science skills	Doing science
II. Knowledge of teaching science content using various strategies	Students have low test scores Students need to increase content knowledge	Learning science (content)
III. Knowledge of teaching science through enhancing students' motivation	Students are not interested in science Students need to increase their motivation to learn science	Learning science content Learning to do science Liking science

In the second study we concluded that science teachers' unique PCK could be typified by investigating the content of the PCK components. Types of PCK could be determined by the content of the PCK components and the relationships between those components. We also concluded from this study that the teachers' concerns and their orientations influenced the content of the other PCK components. Components of PCK influenced one another and were closely related to each other. When teachers were seeking ways to improve their teaching, the PCK components interacted strongly with their concerns and purposes and thus typified the teachers' PCK. In this study we concluded that the PCK types did not mutually exclude one another. Although teachers may have a PCK that focuses on teaching science skills, this does not mean that they do not intend to have their students learn science content knowledge and vice versa.

This study, however, did show evidence that the teachers' concerns and their purposes of teaching, and thus their orientations toward science teaching, determine their PCK type. Therefore, it was concluded teachers' concerns

and purposes of teaching should play a prominent role in future research on types of PCK.

6.2.3. Study III

To answer the third research question, using the Clarke and Hollingsworth (2002) interconnected model of teachers' professional growth (IMTPG), we used different data sources of the twelve science teachers from the second study. According to Clarke and Hollingsworth (2002), pathways that lead to changes in teachers' professional knowledge, can either be a change sequence, or a growth network. In this study, three distinct pathways were found, where only two of those pathways led to changes in the science teachers' PCK (see Figure 6.1). In particular, we found that there were differences in the growth networks. In the simple growth networks, changes in teachers' knowledge seemed to occur without the Domain of Consequence. These teachers simply reflected on the lessons as prepared and taught. In the complex growth networks, however, teachers reflected on the outcomes of their teaching using the Domain of Consequence. These teachers were able to report what they had learned from their lessons, their classroom, and their students, and how this inspired them to revise their teaching. In addition, we found that peer discussion and literature reviews altered the teachers' knowledge of instructions, whereas consulting academic staff altered their knowledge of the curriculum.

The IMTPG model is a suitable model to study teachers' growth. The strength of this model lies with its ability to have teachers reflect upon their thoughts and their actions. These reflections make teachers' growth processes explicit. This model is a useful analytical tool for making PCK changes explicit by outlining the processes of change. The IMTPG model has great potential in PCK research. In an earlier study, Justi and Van Driel (2006) argued that the IMTPG model can also be used as a predictive tool in professional development programs, where the structure of events in the PD program can act as a mechanism to promote teachers' change. In particular, with this

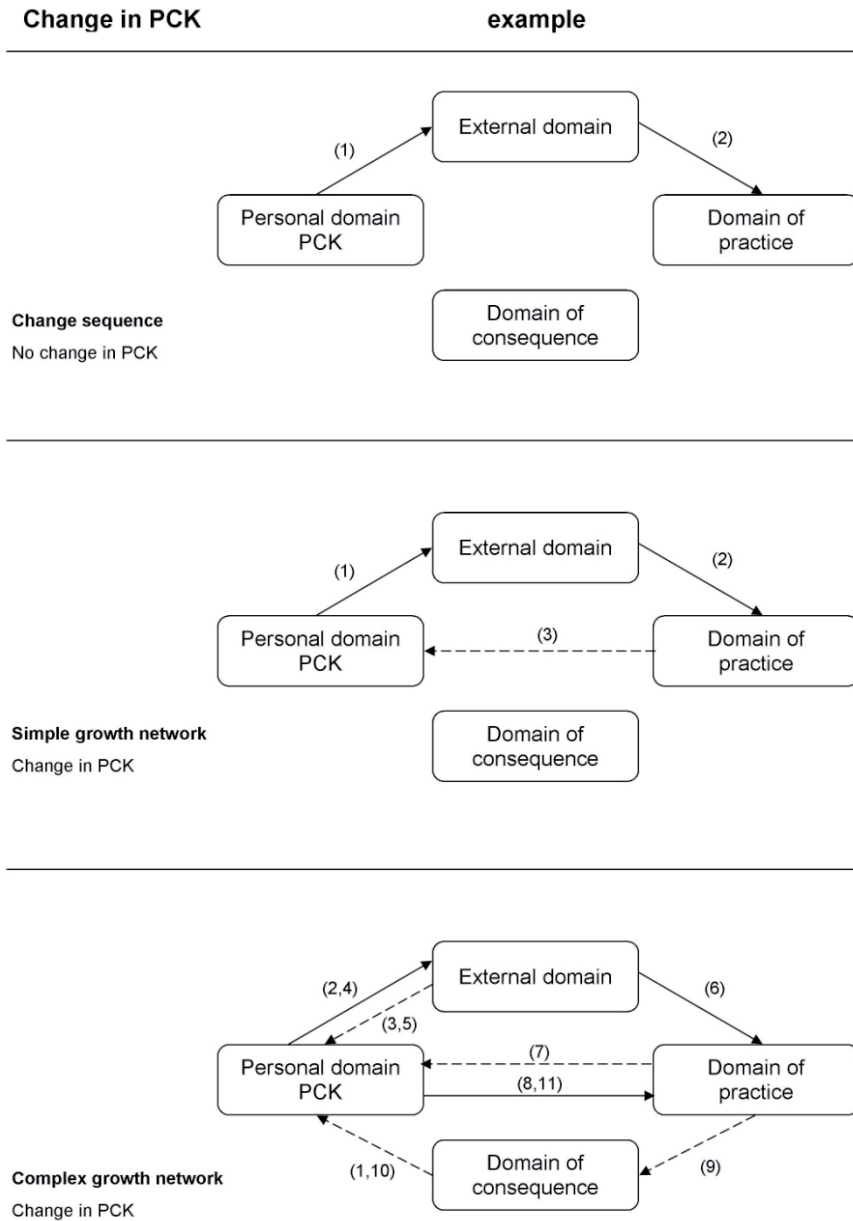


Figure 6.1. Examples of different pathways of change which may or may not lead to PCK development

model, teacher educators can select those aspects in the PD program that promote the development of teachers' knowledge.

From this study we can conclude, with the use of IMTPG as an analytical tool, that the MSP influenced the teachers' PCK, which in some cases enabled teachers to alter their classroom actions. In particular, we concluded that teachers' reflections were important features in PCK development, since they allowed teachers to confirm certain teaching beliefs or construct new knowledge.

6.2.4. Study IV

To answer the fourth research question, we studied 24 science teachers from the last cohort (2006-2007) who engaged in inquiry-based teaching. Using a four level of inquiry model (Bell et al., 2005), we found that teachers who engaged in a *confirmatory* level of inquiry were concerned about the low test scores and the gap in content knowledge of their students. Their classroom activities were all teacher-centered and focused on learning content. Teachers who engaged in the *structured* level of inquiry were still content-driven, but also skill-driven, and used a lot of hands-on activities to teach their inquiry-based lessons. In addition to their concerns about low test scores and lack of content understanding, the teachers were also concerned that the students lacked inquiry skills and were therefore not able to do science. Teachers who engaged in *guided inquiry* were concerned that their students lacked inquiry skills and that they did not get enough real world inquiry experience. They used student-oriented activities such as experiments and classroom projects. The teachers who engaged in *open inquiry* wanted their students to apply inquiry skills to real world situations, so that they gained experience in real science. They had their students design their own projects and come up with their own research questions.

From the fourth study we concluded that teachers' concerns and their orientations were major factors in influencing their classroom actions. In

particular, teachers' concerns, together with their orientations, influenced the inquiry level of science teachers' instructions when they prepared inquiry lessons. We concluded that the teachers using the first two levels of inquiry, confirmation and structured inquiry, had almost the same concerns and science teaching orientations. Teachers using the higher two levels, guided and open inquiry, had distinctly different concerns and different teaching orientations. We also concluded that science teachers' concerns played an important role in the level of inquiry. When the concerns were limited to classroom matters such as lack of content and lack of science skills, the teachers' inquiry-based instructions were found to be in the lower levels. However, when teachers expressed broader concerns, such as about connection with real life and application or understanding of the real world, their level of inquiry-based instructions increased to the higher levels.

6.2.5. The MSP program

We concluded from our research that use of the MSP as a professional development program allowed teachers to develop their PCK, using specific elements in this program. Use of action research in the classroom, in particular, enabled them to engage in classroom actions and to reflect on those actions inducing changes in their PCK. The use of specific elements in the MSP were crucial in determining science teachers' PCK. A special feature of the MSP was the Summer Institute, where teachers got to learn about action research and had the opportunity to work with academic staff and discuss their project with peers. The use of action research throughout the whole school year and the use of a reflective journal were also key factors in having teachers gain experience and reflect on those experiences. Abell (2008) noted that teachers' knowledge can change through experience. Teacher programs allow teachers to gain as much possible experience in teaching and get opportunities to reflect in order to build up a well-defined PCK over time. We concluded that the structure of the MSP allowed teachers to gain experience (including inquiry experience) by using their PCK and reflecting on this knowledge.

6.3. Discussion

The results and conclusions from the studies revealed that the science teachers' pedagogical content knowledge was an important and complex phenomenon. The PCK model of Magnusson et al. (1999) proved to be a useful framework in the four studies of this dissertation. Magnusson et al. (1999) portrayed relations between the five PCK components of science teachers, giving special attention to their orientations to science teaching. We found that the teachers' PCK guided their classroom decisions. This finding is based on the studies where science teachers used their knowledge to plan their activities. Their teaching orientations and their concerns were especially closely related to their practice (Study 4). In Study 2 (Chapter 3), we also found that it was possible to determine the teachers' PCK type.

6.3.1. Orientations towards science teaching

The Magnusson et al. (1999) PCK model illustrates the teachers' 'orientation towards science teaching' can be seen as a 'conceptual map' that shapes the other components of science teachers' PCK, making it an important component in the model. Research on orientations to teaching has shown, however, that these orientations are not static, rigid and well-defined concepts (Abell, 2007; Friedrichsen & Dana, 2005; Talanquer et al., 2010). In our studies, we found that teachers did not hold a 'single' orientation from the Magnusson et al. (1999) orientations list, but may have held multiple orientations from that list, making these orientations rather complex to study. For example, some science teachers who were didactically oriented also expressed ideas that are indicative of a hands-on approach to teaching. We found that science teachers' orientations could be integrations of multiple orientations presented by Magnusson et al. (1999). Earlier studies confirm this finding (Friedrichsen & Dana, 2003, 2005; Anderson, 2007).

In our first study, we found evidence that teaching orientations were indeed greatly influenced by the teachers' goals and their intentions to

teach following a certain strategy. These teaching goals seemed to reflect two of the Hodson (1992) science goals for learning: learning science (or math) and doing science (or math). Hodson's (1992) third goal, learning about science, was not encountered in this study. Using the first two goals of Hodson (1992) and the teachers' intentions on how to reach those goals, we were also able to capture the teaching orientations in three main categories: content-driven with teacher-centered activities, content-driven with student-centered activities, and skills-driven with student-centered activities (see Chapter 2). In each category we also encountered variations in the teachers' orientations. These variations were mainly based on teachers' additional goals and their classroom concerns. We concluded that, although teachers had common main orientations, their individual orientations were rather unique. Friedrichsen and Dana (2003; 2005) refer to these additional goals as peripheral goals. They explain that teachers have multiple goals that influence the nature of their orientations. In our study we concluded that although main goals were useful to determine main orientations of teaching (Talanquer et al., 2010), additional goals were equally important to gain a deeper understanding of these orientations that drive other PCK components (Friedrichsen & Dana, 2005). For example, we found that when a teacher was interested both in teaching content knowledge and increasing students' motivation, he or she portrayed an orientation 'motivate student to learn content knowledge'. While another teacher whose goals were to increase students' content knowledge and their ability to retain this knowledge, portrayed an orientation 'have students learn science or math skills to retain content knowledge'. Both teachers had a similar main orientation (content-driven using student-centered activities), but had different emphases and thus portrayed specific individual orientations.

We found that the nine Magnusson et al. (1999) orientations reflected the purposes, goals, and instructional strategies from our first study. For example, the Magnusson et al.(1999) orientations: inquiry, project work, hands-on, and didactics were coded in our study as teachers' goals or as

intended instructional strategies. Knowing that science teaching orientations are more complex than the ones found in the Magnusson et al. (1999) study, it may be time to re-consider the orientations of Magnusson et al. (1999) and to investigate how the complex nature of these orientations can best be captured and classified. Recently, Friedrichsen et al. (2011) noted that the definition of teaching orientations is still blurred, since multiple explanations have been given to the same concept. While some scholars explain teaching orientations as ‘the goals and purposes of science teaching’, other scholars have explained the orientations as ‘a general way of viewing teaching science’ (Friedrichsen et al., 2011, p. 366). More research is needed to (1) give clarity to this concept and (2) reexamine the orientations of the Magnusson et al. (1999) study.

6.3.2. Science teaching concerns

In our study we found that teachers’ concerns were closely linked to their teaching orientations. The PCK model of Magnusson et al. (1999) indicates that teaching orientation is the one component that ‘shapes’ other knowledge components. In our research, however, we found that teachers’ concerns also influenced the PCK components (Chapter 3) as well as teachers’ practice (Chapter 5). We found that although the teachers had certain teaching orientations, their concerns were evidently present when we investigated their PCK. In Chapter 3, we typified the teachers’ PCK and found that their purposes for teaching, their teaching orientations, and their concerns played a major role in ‘shaping’ the other PCK components. In-service teachers’ concerns originated from their teaching experience. When the science teachers in our study reflected on past experiences, they all expressed a certain concern, which was related to their teaching goals and purposes, namely their orientations. Research focused on pre-service teachers’ concerns mentions that investigating in-service teachers’ concerns can help us understand why and how teachers use their knowledge to conduct their lessons (Melnick & Meister, 2008). In our fourth study (Chapter 5), we found that teachers’ concerns were closely linked to their inquiry-based lessons,

and we therefore concluded that these concerns influenced teachers' decisions when preparing and conducting lessons. Earlier studies have noted that classroom management is one of the most important concerns of pre-service teachers (Melnick & Meister, 2008). In our fourth study (Chapter 5) we found that understanding and retaining content knowledge, mastering science skills, and motivating students, were the most important concerns of in-service science teachers. Understanding the concerns and how these concerns influence teachers' knowledge and actions could enhance our understanding of how teachers draw upon their PCK to conduct and prepare lessons. From our experience of doing this research, we conclude that teachers' concerns influence their teaching orientations as well as the other PCK components. However, whether the teachers' concerns influenced their orientations, and therefore influenced the other PCK components, or whether these concerns influenced all PCK components directly is open to debate (Figure 6.2).

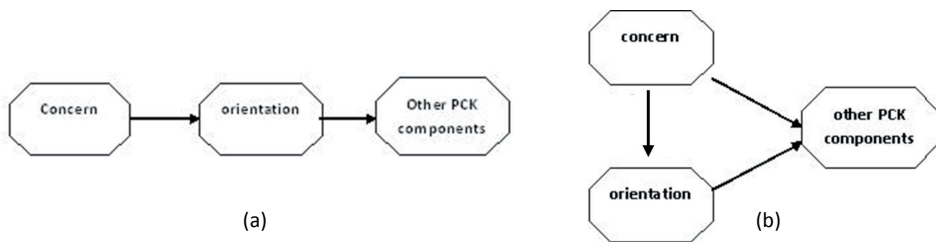


Figure 6.2. Two ways teachers' concerns could influence PCK components

More research is needed on the nature of in-service science teachers' concerns and their influence on their PCK. Knowledge of in-service teachers' concerns can be useful to design programs aimed at pre-service teachers, who start making the transition into the classroom as beginning teachers and then later on as experienced teachers. Shifts in concerns may occur, which may lead to PCK development. We wonder how PCK develops over time and how shifts in teachers' concerns may play a role in this development. Future longitudinal research on concerns is needed to determine how PCK

is influenced by these concerns, which in turn influence the teachers' lesson plans and their practice.

6.3.3. Models for PCK development

In our third study (Chapter 4) we used a model to understand PCK development. A lack of understanding of teachers' knowledge development (Beijaard et al., 2000; Eraut, 1994) makes models extremely useful for studying teacher development. Different models have been offered over the years (Bell & Gilbert, 1996; Borko, 2004; Clarke & Hollingsworth, 2002; Fraser, Kennedy, Reid & McKinney, 2007; Guskey, 1986). We used the model of Clarke and Hollingsworth (2002), which was adapted from Guskey's model of teacher change (1986), to study teachers' professional growth. Clarke and Hollingsworth (2002) altered Guskey's (1986) model, explaining that teacher change is not a linear, but rather a cyclic process (see Chapter 1 and Chapter 4 for a discussion of the IMTPG model).

Justi and Van Driel, (2006) noted that when teachers engage in action research, connections between the Domain of Practice and the teachers' Personal Domain can be established. They found that reflective relationships dominate the growth networks of the teachers' knowledge development. The present study supports their finding that when teachers conduct action research in their classroom changes in their knowledge often occur. We found that the action research did indeed allow teachers to reflect on their classroom situation, making relationships between the Domain of Practice and the Personal Domain evident. However, we also found that a personal reflective journal was useful for establishing deeper relationships between the External Domain, the Domain of Practice, the Domain of Consequence and the Personal Domain. In the teachers' reflective journals we found evidence that teachers who could reflect from the Domain of Consequence were also able to translate their changed knowledge into new practices. The teacher interview was, in addition to the teachers' reflective journal, another valuable tool for gaining deeper understanding of the processes underlying

these changes. During the interview the teachers could explain why they enacted certain classroom decisions and how they reflected upon these actions.

The IMTPG model is a useful model for analyzing PCK changes in a teacher. The use of participants' action research in combination with the IMTPG model allows robust research in PCK development and provides useful insights into the processes of PCK changes in a teacher. Useful data collection tools include the use of action research reports, teachers' written material, teachers' interviews, and personal reflective journals to capture the underlying thoughts of teachers. Other professional development models should also be explored to give new perspectives on PCK development. Borko (2004) offered a model where four crucial elements are interconnected: the teachers, the PD program, the facilitators, and the context. In our study the context was the action research project. Van Driel et al. (2001) posited that PCK is context-bound, making Borko's (2004) PD model another model to consider when exploring PCK development.

6.4. Strengths and weaknesses

6.4.1. Strengths

Many professional development programs use a top-down approach when having teachers participate in the program (Desimone, 2009). In this study we did not investigate topic-specific PCK research, where all teachers teach the same concept at the same grade level. We wanted the teachers to develop their own thinking, present their own thoughts and develop their own knowledge and skills necessary for teaching. Studying teachers who can choose and investigate their own 'troubled' concepts and develop their own action research provides a deeper understanding of their teaching concerns and the thoughts and beliefs that underlie their knowledge and ultimately their actions. The combination of teachers' action research and the Summer Institute within a professional development program provided

a solid framework in this study. Action research not only allows teachers to conduct research in their own classroom, but also creates opportunities for them to be creative in improving their own teaching. Action research, through teachers' reports and their reflective journals, gave us insight into how teachers think, act and construct new knowledge.

We used triangulation to collect data from multiple sources to capture a deeper scope on the knowledge of teachers and to maintain the credibility of this study. Patton (2002) notes that 'one can compare the consistency of findings generated from different data sources within the same method' (p. 556). Triangulation was used in different forms: the use of multiple data sources and the use of multiple groups of teachers from different cohorts. The use of multiple cohorts enabled us to study a heterogeneous group of teachers when investigating PCK elements.

6.4.2. Weaknesses

All the research instruments used in our studies produced data of teachers' expressions in written or verbal forms. We only showcased the knowledge, beliefs, and attitudes that teachers were able to express. We did not capture their practices through observations in the classrooms, but only captured them when the teachers mentioned them in their lesson plans and progress reports or talked about these skills in an interview. Classroom observation would provide data which could make this research more reliable. Classroom observation data would also allow to explore the consistency of the data used in the present study, with the teachers' practice.

One other weakness in the present study, was the fact that we did not capture the teachers' context thoroughly. Teachers' context is an important aspect in understanding the knowledge that teachers use in their practice. Since PCK is context-bound (Van Driel et al., 1998), including teachers' context in this research would have provided us with useful insights on how teachers' orientations and concerns are related to their PCK within a certain context. In

our study, however, we chose to use the IMTPG model to study the teachers' change processes. The Clarke and Hollingworth's (2002) model proved to be suitable for studying this change, although it does not account for the teachers' context.

We did not focus on student understanding or student outcomes in relation to teachers' PCK. That would have gone beyond the scope of our study. However, investigating student understanding and student outcomes in relation to the teachers' PCK could have helped us to understand how PCK actually influences student learning. It thus remains an important aspect for future research on PCK to conduct frequent investigations in classroom settings, taking the learners into account.

6.5. Implications and suggestions for future research

6.5.1. Practical implications

Understanding PCK use and PCK development is critical for the success of science teaching education (Abell, 2007). Teacher educators, for instance, could have their pre-service teachers observe experienced teachers in the classroom, but teachers' knowledge is often tacit and not easily understood by novice teachers. Furthermore, prospective teachers must consider teacher cognition a valuable aspect and should not only focus on teacher behaviors (Verloop et al., 2001). Teacher educators play an essential role in helping their students understand the knowledge that underlies the behavior of experienced teachers. The results of this study may help teacher educators to understand what PCK in-service science teachers use when they plan and conduct their teaching. Understanding teachers' pedagogical content knowledge and the development of this knowledge is important for innovative teacher training programs. More research is needed to inform teacher educators how PCK is translated into practice. This research should inform the educators about whether and how the translation finds its way into positive student outcomes. In general, PCK research of how pre-service

teachers' make the transition to beginning teachers and how their PCK changes over time, would be useful for teacher educators. They might benefit from these longitudinal studies to adjust their teaching programs to facilitate the PCK development of their prospective teachers. We agree with scholars such as Shulman, Grossman, and Magnusson that PCK development should be the primary goal of science teacher education. We also recommend that science teacher educators use a PCK model as a framework in their courses. The PCK model of Magnusson et al. (1999) is recommended to be used for this framework.

Our research found that the MSP program was a robust program for understanding and developing the PCK of in-service teachers. The combination of the two-week Summer Institute and the one-year action research project gave the teachers the opportunities to (1) reflect upon their own teachings; (2) develop new knowledge and skills to improve their lessons; and (3) reflect upon their experience and build upon new knowledge suitable for use in their classroom teaching. Van Veen, Zwart, Meirink, & Verloop (2010) described seven characteristics that define an effective professional development program: (1) content knowledge and pedagogical (content) knowledge; (2) active learning and inquiry learning; (3) collective and collaborative participation; (4) length of the PD program; (5) quality of resources; (6) related to (educational) policies; and (7) theory of improvement. The MSP offers the participants the possibility of increasing their content knowledge and their pedagogical content knowledge. The program also offers teachers the opportunity to be engaged in collaborative inquiry learning through the use of action research. Furthermore, this one-year program, which is tied into educational policies through the Illinois State Board of Education, offers participants the opportunity to make use of resources such as consultations with peers and academic staff. Advocating for life-long learning, teachers around the world should have the opportunity to participate in programs to develop their own professional knowledge, taking those PD characteristics into consideration. The MSP program could be an

example for other PD programs. The MSP could also be offered to classroom courses other than the mathematics and science courses which are offered in the students' curricula. If we want to have teachers continue to work on their own professional development, then PD programs such as the MSP would be effective to offer to in-service teachers. The results from the MSP as reported in this dissertation provide us with information to improve our conceptualizations and measures of PCK and PCK development. Insightful scopes from the MSP could help to elevate the quality of professional development programs and to elevate our understanding of ways to shape and implement teacher learning opportunities, which could lead to the development of strong PCK that would benefit both teachers and students. The use of action research and the use of a reflective journal during the action research projects were good examples from this MSP that helped us to understand how teachers translate their knowledge into practice.

6.5.2. Research implications

In different sections of this thesis we have already mentioned several implications for research. Many studies have focused on PCK development and PCK structure, but few studies refer to PCK structure and PCK development of experienced science teachers in a professional development setting (Van Driel et al., 1998; Henze et al., 2008). In this study we show what PCK teachers used when they participated in a professional development program to improve their teaching. The study also provided insights into the processes of PCK development in the context of a professional development program. The results of this study could be useful to future researchers attempting to gain a deeper understanding of how and why teachers use PCK in their lessons. In particular, the role of teachers' concerns in the structure of PCK has not been studied well (Chapters 2 and 5), nor has the influence of teachers' orientations on their practice been studied extensively (Chapter 5). One main focus of continuing research should be on understanding how PCK is actually translated into practice. A model that explains how teacher knowledge is actually translated into practice could be used with multiple

data sources to help us understand how teachers use their PCK in practice. First hand empirical data such as classroom observations, teacher journals and teacher interviews could be useful data sources in such research.

Another focus of future research could be the investigation of longitudinal processes that underlie PCK development. Robust instruments need to be developed to capture rich empirical data to describe the development of PCK. In the present study, teachers' reflective journal proved to be a useful tool, as well as the teachers' action research reports, their lesson plans, and the interviews (Chapter 4), but they are not extensive enough for longitudinal studies. Additional creative instruments, such as teacher and student diaries, and field texts (Mulholland & Wallace, 2005), could be developed to create longitudinal datasets which are needed to design and test models for continuing PCK development.