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

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Summary

This dissertation reports on four studies in which the pedagogical content knowledge of science teachers was examined during a professional development program. Pedagogical content knowledge (PCK), one of the seven knowledge bases required for teaching, is described as that *unique* knowledge of teaching that aims to make students understand the content of science (Shulman, 1986). In this dissertation we examine the PCK of experienced in-service science teachers in relation to their educational beliefs, to help us understand why and how teachers make their classroom decisions as they teach science. Understanding this particular body of knowledge could help us guide and develop ‘good science teaching’ in our teacher education programs.

Chapter 1: Introduction

The introduction chapter gives an overview of the background of the research, the theoretical framework for examining PCK, and the structure of this dissertation. In this chapter we discuss the literature on PCK, which was first introduced by Shulman as ‘that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding’ (1987, p. 8). After Shulman (1987), Grossman (1990) and later Magnusson, Krajick, and Borko (1999) proposed a PCK model consisting of the following components: (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). In this model, the orientations toward science teaching are seen as the PCK component that 'shapes' the other components.

We used the Magnusson et al. (1999) model to study the content of PCK when science teachers participated in a professional development program called the mathematics and science partnership program. We also describe the PCK development of science teachers in the context of this professional development (PD) program. The mathematics and science partnership program (MSP) is a professional development program aimed at promoting teachers' abilities to enhance students' learning. For this purpose, the main goals of the MSP include increasing teachers' content knowledge, increasing their pedagogical content knowledge, and use of action research in the classroom. The MSP program was designed to have teachers use an action research approach to study and reflect on both their content knowledge and their pedagogical content knowledge with help from academic staff. The MSP started with a two-week Summer Institute where mathematics and science teachers were introduced to action research and where they prepared an action research plan for the following school year. To prepare their plans, teachers selected their own science or math topic, sought advice from academic staff who acted as their mentors, and participated in peer discussions. In the following school year, the teachers met with their mentors on four follow-up days spread out over the year. All the participating teachers worked on their action research throughout the year, wrote their own progress report, and kept a reflective journal. At the end of the school year, the teachers finalized and submitted their progress report as their final action research report together with their lessons plans and students' artifacts. For our research purposes, some teachers were asked to voluntarily participate in an interview. The MSP was conducted in three consecutive years with three different cohorts. The cohorts included math and science teachers (see Table I).

Table I.
Number of math and science teachers per cohort

Cohort	Mathematics teachers	Science teachers
I	16	16
II	18	14
III	19	24

The main questions in this study were: *What is the pedagogical content knowledge of science teachers² 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 professional development program?*

To answer these questions we conducted four studies where we used the teachers' action research plans, their progress reports, their lessons plans, and the interviews as multiple data sources in the different studies.

Chapter 2: Orientations toward teaching of mathematics and science teachers

This study reports on the teaching orientations of 107 math and science teachers who participated in the three cohorts of the MSP program. The main question for this study was: *What are the orientations of science and mathematics teachers to teaching science or math in the context of a professional development program?* We used the teachers' action research plans, their lesson plans, and their reflective journals to investigate their teaching orientations. We investigated the goals and purposes for teaching from the action research plans, as well as the teachers' intentions to use certain instructional strategies in their lesson plans. The analyses of the data from the teachers' action research plans and their lesson plans resulted in the identification of three main orientations: (1) content-driven with the intention

2 This dissertation focuses on science teachers but in study 1 we also studied the orientations toward teaching of mathematics teachers.

of using teacher-centered classroom strategies; (2) content-driven with the intention of using student-centered classroom strategies; and (3) skills-driven with the intention of using student-centered classroom strategies. From the data analyses we found that although teachers had the same main orientation, individual orientations may differ within a main orientation. We found that teachers had multiple goals and different intentions for using a specific instructional strategy. These goals and different instructional strategies resulted in teachers having different emphases within their main orientations. For example, when two teachers had a 'content-driven and student-centered activities' orientation, one teacher may want to increase the students' content knowledge by using *inquiry*, while the other teacher may intend to increase the students' content knowledge by *motivating* the students to learn content.

Chapter 3: PCK types of science teachers

In this chapter we typified science teachers' PCK in a professional development setting. Twelve science teachers were interviewed after they submitted their action research report and their reflective journals. We used these data sources to determine what type of PCK the teachers drew upon when they intended to improve their science teaching. The central question of this study was therefore: *How can in-service science teachers' pedagogical content knowledge be typified at the end of a professional development program aimed to improve their teaching?* To study the teachers' PCK, we made PCK representations of these twelve teachers, using the Magnusson et al. (1999) PCK model. Based on the teachers' PCK representations, we categorized their PCK in three types: (1) knowledge of teaching science process skills; (2) knowledge of teaching science content using various strategies; and (3) knowledge of teaching science through enhancing students' motivation. The types were primarily based on the teachers' goals and purposes for science teaching. Two of the goals, teach science content and teach science skills, showed similarities with Hodson's (1992) science goals for learning: (1) learn science and (2) learn how to do science. In this study, we did not find

Hodson's third goal, learn about science, but we found an additional goal: increase students' motivation to learn (how to do) science. PCK type III focused on this goal. We found that the teachers' goals in their projects were linked to their classroom concerns and portrayed a PCK that was typified by their goals and concerns. Based on the results from this study we found that teachers who were concerned about their students' poor grades in science stated that their goal was to have students increase their content knowledge and therefore they had a PCK representation that was focused on teaching content knowledge (type II). Teachers who had PCK type I, teaching science skills, stated that their students lacked the inquiry skills to learn science. PCK type III teachers stated that their students were bored with science and therefore did not do well in the subject, so their aim was to motivate their students to become interested in science. We found that both factors, teachers' concerns and their purposes for teaching science, influenced science teachers' PCK. When science teachers were seeking ways to improve their teaching in a professional development context, we found that their PCK components interacted strongly with their concerns and purposes and thus helped typify the teachers' PCK.

Chapter 4: PCK development of science teachers

In the third study we investigated the development of the pedagogical content knowledge of the previously selected twelve science teachers when conducting their action research projects. We used the interconnected model of teachers' professional growth (IMTPG) (Clarke & Hollingsworth, 2002) to study changes in the participants' pedagogical content knowledge. The research question for this study was: *What are the possible pathways that lead to changes in science teachers' pedagogical content knowledge in a professional development program?* The IMTPG model consists of four different domains which interact to foster teachers' professional growth: (1) the Personal Domain, which contains teachers' knowledge, beliefs, and attitudes; (2) the External Domain containing external sources of information or stimuli; (3) the Domain of Practice, which involves professional classroom

experimentation; and (4) the Domain of Consequence containing salient outcomes related to classroom practice. We collected the teachers' action research reports, their lesson plans, and the interviews to investigate their PCK development. Using the IMTPG model we identified three distinct types of pathways with regard to teachers' pedagogical content knowledge development (see Figure I).

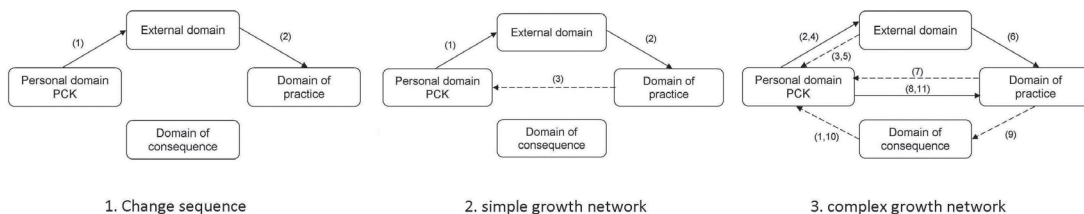


Figure I. The different pathways

The first pathway is considered a change sequence and indicates that although a change in practice was noted, no change occurred in the teacher's PCK. The second and third pathways are considered 'growth networks' and indicate that science teachers' PCK did change. Clarke and Hollingsworth (2002) argue that growth networks indicate lasting changes in teachers' practice and their knowledge (pp. 958-959). In this study we found two types of 'growth networks'. The 'simple growth network' did not include the domain of consequence (see Figure I.2). This indicates that the teachers only reflected on their lessons when they were preparing and teaching them in class. They did not, however, reflect on the outcomes of their lessons. The 'complex growth network' included the domain of consequence (see Figure I.3). From this growth network we found that, through the domain of consequence, the teachers reflected on their teaching and on their students' learning. These teachers could specify what and how students learned. Through these reflections we inferred that obvious changes occurred in their pedagogical content knowledge. We also found that in some cases teachers who reflected on their students' learning were able to alter their classroom practice on the basis of these reflections (see arrows 9, 10 and 11 in Figure I.3).

In addition, we found that the MSP program offered some interesting features that fostered PCK development. In the IMTPG model, the MSP program was located in the external domain referring to external stimuli that the teachers received from this PD program. From this study it became evident that within the external domain, the role of the university staff was particularly important in the development of teachers' PCK. Having the university staff on site was a critical factor in helping participants develop new understandings of students' learning. This was the case in all three types of pathways found for the development of the PCK component 'knowledge of student understanding'. We also found that teachers learned about new instructional strategies and assessment methods when they were able to review literature and discuss their findings with peers.

Chapter 5: Relations between PCK components and science teachers' inquiry practice

This chapter describes the study conducted in the third cohort of the MSP program, in which 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. The main question for this study was: *What is the relation between teachers' concerns, their orientations towards science teaching, and inquiry-based instructional levels of inquiry when they design and conduct lessons?* The teachers' action research reports, their lesson plans and their reflective journals were used as data sources for this study. To determine the level of inquiry of 24 science teachers we used the inquiry model of Bell et al. (2005) which distinguishes between four levels of inquiry teaching: (1) the confirmation level; (2) the structured level; (3) the guided level; and (4) the open level of inquiry. In our study 'confirmation' and 'structured inquiry' were considered lower levels, whereas 'guided inquiry' and 'open inquiry' were considered higher levels. We found that the teachers' orientations and their concerns connected to the lower inquiry levels differed from the

orientations and concerns of teachers who used inquiry-based instructions at the higher inquiry levels.

Science teachers who used inquiry-based instructions at lower levels were mostly concerned about their students' low grades. They also found that their students lacked science content knowledge, and inquiry skills. When investigating these teachers' orientations, we found that they were 'content-driven', 'skills-driven', and 'activity-driven', as well as focused on 'academic rigor' and 'didactics'. Furthermore, the lower level inquiry teachers engaged their students in classroom activities that were mostly teacher-centered, teacher-structured or teacher-induced. Comparing these teachers with the science teachers who used inquiry-based instructions at higher levels, we found that those teachers had concerns that included 'students lacking inquiry skills' and 'students lacking real world inquiry experience'. We found that these teachers also had 'content-driven' and 'skills-driven' orientations, but that their orientations were combined with other orientations such as, 'inquiry', 'discovery' and 'project-based'. Furthermore, the teachers who engaged in the higher levels of inquiry mostly included student-centered activities in their lessons.

Chapter 6: Conclusions and discussion

Based on the results of the four empirical studies, our conclusions and the main discussion are presented in Chapter 6. From the first study we concluded that the teachers participating in the MSP program had complex orientations. Although the study suggested that the teachers' orientations could be categorized in one of the three main orientations, individual teachers' orientations remained unique. On an individual level, each teacher had multiple goals and a variety of instructional strategies that resulted in a unique orientation. In their study, Magnusson et al. (1999) presented nine different orientations: (1) activity-driven; (2) didactic; (3) discovery; (4) conceptual change; (5) academic rigor; (6) process; (7) project-based; (8) inquiry; and (9) guided inquiry. These orientations were distilled from the

research literature on science teaching and Magnusson et al. (1999) ascribed one orientation to each individual teacher. In our study however, we found that the teachers did not have 'single' orientations as presented by Magnusson et al. (1999). We therefore concluded that although teachers have one main orientation, their orientations are complex because of different emphases, due to their multiple goals and strategies.

The main conclusion from the second study was that science teachers' PCK can best be typified when their concerns, goals, and purposes in teaching science are taken into consideration. We furthermore concluded that the science learning goals of Hodson (1992) were important goals for science teachers, and that motivation to learn science was another important goal when typifying science teachers' PCK.

In the third study we found that teachers' PCK development followed different pathways of change. Pathways of change can be categorized into change sequences, simple growth networks, and complex growth networks. In our study we concluded that only the two latter pathways led to changes in the teachers' PCK. Teachers with simple growth networks had pathways without the domain of consequence. They showed changes in PCK but these changes did not result from the teachers reflecting on their classroom outcomes. Usually these changes occurred because the teachers reflected on how they planned their lessons. Teachers with a complex growth network (including the domain of consequence) appeared to reflect on the outcomes of their students' learning. We therefore concluded that the domain of consequence was an important domain for identifying lasting changes in teachers' PCK.

In the fourth study we concluded that teachers' concerns and their teaching orientations were closely related to their planning of inquiry-based instructions. We also concluded that teachers using lower levels of inquiry instructions engaged in teacher-oriented activities, whereas teachers using higher levels of inquiry instructions engaged in student-centered activities.

Our research led us to conclude that the Magnusson et al. (1999) PCK model is useful when investigating the content and development of science teachers' PCK. PCK representations of teachers can be drawn based on the five different components in this model. These PCK representations helped us to understand the relationships between the different components, which in turn offered interesting insights into the nature of PCK types. We found Hodson's (1992) science learning goals useful when determining the teachers' goals for teaching. Additional goals such as 'motivating students to learn science' also appeared to be important when examining teachers' orientations toward teaching science in relation to their other PCK components. It became evident that both teaching orientations and teachers' concerns can influence science teachers' PCK. Science teachers' concerns, in particular, deserve more attention in research on science teachers' pedagogical content knowledge.

We believe that PCK is tacit knowledge and we used multiple data sources, such as teachers' reports, their lesson plans, reflective journals, and interviews, to try to capture that knowledge. We found that these were valuable tools in grasping the content of PCK from the data. However, using classroom observations, would have enabled us to see how the PCK is actually translated in the classroom, and how students respond to this. In addition to using classroom observation in future research, we believe that large-scale and longitudinal research studies are needed. Using a greater number of respondents could give a better understanding of the different types of PCK found within in-service teachers and using instruments to capture the complexity of this particular teacher knowledge over a longer period of time could deepen our understanding of how PCK transforms in the context of teachers' own practices.