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

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Chapter 2. Understanding orientations towards teaching of mathematics and science teachers in the context of a professional development program

Abstract

This study was designed to identify and characterize in-service teachers' orientations towards teaching math or science when they participated in a Summer Institute to plan action research to improve their teaching. Teachers' goals play an important role in determining their orientations towards teaching. Using resources such as teachers' plans and reflective journals during the Summer Institute, we were able to identify four major goals that determined their teaching: teaching content knowledge, teaching skills, teaching inquiry, and motivating students to learn math or science. We found three main orientations towards teaching: content-driven using student-oriented activities, content-driven using teacher-oriented activities, and skills-driven using student-oriented activities. Within these main orientations towards teaching we found that teachers have different emphases in their orientations.

Keywords: orientations toward teaching, pedagogical content knowledge

2.1. Introduction

Teachers' knowledge and beliefs play an important role in the planning and conducting of classroom teaching (Talanquer et al., 2010). Scholars have argued that teachers hold strong beliefs about teaching and learning (Abell, 2007). These beliefs 'lie at the very heart of teaching' (Kagan, 1992, p. 85). Research is therefore needed to understand the knowledge and beliefs teachers use for planning and conducting their lessons. Teachers' knowledge and beliefs have been the scope of interest in understanding their action and practice. For years, educational researchers studied pedagogical content knowledge as part of the knowledge base of teaching, aimed to help students gain a good understanding of specific subject matter (Lee & Luft, 2008; Loughran, Milroy, Berry, Gunstone & Mulhall, 2001; Loughran, Mulhall & Berry, 2008; Nilsson, 2008; Friedrichsen, Abell, Pareja, Brown, Lankford, & Volkmann, 2009; Henze et al., 2008). According to Gess-Newsome (1999a), 'PCK that helps students understand specific concepts is the *only* knowledge used in classroom instruction' (p 12) that influences the decision-making of classroom teaching. In the often cited PCK model of Magnusson et al. (1999), teachers' orientations towards teaching are based on their knowledge and beliefs of goals and purposes of teaching (Magnusson et al., 1999; cf. Grossman, 1990).

Teaching orientations play a critical role in the pedagogical content knowledge of teachers (Friedrichsen & Dana, 2005). Magnusson et al. (1999) argued that teaching orientations serve as 'conceptual maps' that guide a teacher's instructional decisions about the organisation of curricula, classroom activities, student assignments, classroom materials, and the evaluation of students' learning, and thus shape the development of teachers' PCK. Borko and Putnam (1996) state: 'attempts of experienced teachers to teach in new ways are highly influenced by what teachers already know and believe about teaching, learning, and learners' (pp. 684-685).

In this empirical study we focused on the construction of orientations towards teaching. Abell (2007) argued in her review that although orientations play a critical role in distinguishing the quality of teaching, these orientations have not been well studied. According to Friedrichsen and Dana (2005), teaching orientations are not single homologous entities and should better be presented as complex entities with central and peripheral components (p. 237). It is therefore important when investigating teaching orientations to carefully consider multiple components that are part of these orientations and factors that influence these orientations. The aim of our study was to investigate orientations toward teaching science (science teaching orientations) in the context of a professional development program. We wanted to determine what the orientations of science and mathematics teachers would be after they participated in a professional development program to improve their own teaching. To study teachers' teaching orientations, we used teachers' plans including their purposes, goals, and beliefs about teaching.

2.2. Theoretical framework

2.1.1. Science teaching orientations

The construct of PCK has been an issue of debate over the last two decades. After Magnusson et al. (1999) proposed a model of the PCK construct, many scholars have used and discussed this model in their own research. One component called the orientation of science teaching has been heavily debated due to the lack of consensus about its definition (Friedrichsen et al., 2011). Abell (2008) noted that orientations towards science teaching also have been called: conceptions of teaching (Hewson & Hewson, 1987, 1989; Meyer et al., 1999) or preconceptions of teaching (Weinstein, 1990). The pivotal role of this PCK component lies in the decision-making behind the planning and conducting of classroom teaching and reflection upon it.

Following Grossman (1990), Magnusson et al. (1999) defined orientations as teachers' knowledge and beliefs based on the purposes and goals of science

teaching. Teaching orientations are also considered ‘general views about teaching’ (Anderson & Smith, 1987; Magnusson et al., 1999). Magnusson et al. (1999) presented nine different orientations distilled from the research literature on science teaching: (1) activity-driven; (2) didactic; (3) discovery; (4) conceptual change; (5) academic rigor; (6) process; (7) project-based; (8) inquiry; and (9) guided inquiry (see Table 2.1).

Table 2.1.

The nine orientations toward science teaching proposed by Magnusson et al. (1999)

Orientations toward science teaching	Description
Process	Help students develop the ‘science process skills’
Academic rigor	Represent a particular body of knowledge
Didactic	Transmit the facts of science
Conceptual change	Facilitate the development of scientific knowledge by confronting students with contexts to explain that challenge their naïve concepts
Activity-driven	Have students be active with materials, ‘hands-on’ experiences
Discovery	Provide opportunities for students to discover targeted science concepts on their own
Project-based science	Involve students in investigating solutions to authentic problems
Inquiry	Represent science as inquiry
Guided inquiry	Constitute a community of learners whose members share responsibility for understanding the physical world, particularly with respect to using tools for science

The proposed orientations are identified based on two elements: ‘the goals of teaching science that a teacher with a particular orientation would have, and the typical characteristics of the instruction that would be conducted by a teacher with a particular orientation’(p. 97). Magnusson et al. (1999) argued that a teacher’s orientation should not be distinguished by the use of

a particular strategy, but by the *purpose* of using this strategy. In this study, we therefore investigated both the teachers' goals of teaching science, or mathematics, and their intended use of instructional strategies to understand their orientations to teaching.

Friedrichsen and Dana (2003, 2005), who studied experienced biology teachers, reported that science teaching orientations play a critical role in understanding the development of PCK. In their study, the teachers held multiple orientations, influenced by multiple factors, including their beliefs about learners and learning, their prior work experiences, professional development, the classroom context, and time constraints. The use of both peripheral and central goals represented the complex nature of science teaching orientations. Central goals such as 'develop environmentally based decision-making ethics' or 'develop skills and techniques to explore scientific questions' dominated the teacher's thinking and drove the instructional decision-making process. The peripheral goals such as 'develop science process skills' and 'develop laboratory skills' can be seen as supportive to the central goals. Furthermore, Friedrichsen and Dana (2003) found that their biology teachers held different teaching orientations for each course they taught. In a later study, Friedrichsen et al. (2011) mentioned the importance of considering the Hodson (1992) goals for science education when studying teaching orientations. Hodson (1992) distinguished three different types of goals of science education: (1) *learning science*, having students acquire conceptual knowledge; (2) *learning about science*, having students develop an understanding of the nature of science; and (3) *doing science*, having students engage in scientific inquiry and problem-solving.

Koballa, Glynn, Upson and Coleman (2005) presented five 'conceptions about science teaching,' held by science teachers: (1) presenting science content to students; (2) providing students with a sequence of science learning experiences; (3) engaging students in hands-on science activities; (4) facilitating the development of students' understanding about science;

and (5) changing students' science-related conceptions. Koballa et al. (2005) found that teachers' conceptions about science teaching guided their instructional decision-making and were consistent with their teaching practice. While the teachers held one main conception of science teaching, it was possible to hold various conceptions simultaneously. When the teachers attempted to implement 'new' instruction, it created tensions with their existing conceptions about science teaching. The teachers' conceptions about science teaching were formed by their prior experiences and acted as barriers to considering 'new' conceptions about science teaching.

Talanquer et al. (2010) studied teacher candidates' preferences for instructional activities and found that the orientations of these candidates were driven by three central goals: (1) motivating students; (2) developing science process skills; and (3) engaging students in structured science activities. Talanquer et al. (2010) therefore described three orientations towards teaching: 'motivating students', 'process', and 'activity-driven'. Of these three, the last two had also been identified by Magnusson et al. (1999). Motivating students, however, seems like a new orientation towards teaching.

2.1.2. Mathematics teaching orientations

In mathematics education literature, Thompson, Philipp, Thompson, and Boyd (1994) stated that an orientation towards mathematics teaching includes the teachers' knowledge, beliefs, and values about mathematics and mathematics teaching. Thompson et al. (1994) distinguished two major orientations: a conceptual orientation and a calculational orientation. The conceptual orientation is mainly driven by a teacher's way of thinking on how students should develop into productive ways, taking into consideration materials, activities and student engagement. On the other hand, the calculational orientation entails teacher's actions driven by the application of calculations and procedures for obtaining numerical results. This does not mean, however, that the teacher is only focused on computational procedures,

but rather that he or she has a rather inclusive view of mathematics as being about 'getting an answer' (p. 7).

Andrews and Hatch (1999) identified five conceptions or perspectives of mathematics teaching: (1) process-oriented; (2) skills-oriented; (3) focus on the individual child; (4) collaborative and cooperative; and (5) the importance of a mathematically enriched classroom. The process-oriented conception can be seen as a social construction where students are encouraged to develop their own ideas. The skills-oriented conception has an emphasis on routine practice of skills and whole class teaching where 'pupils can gain autonomy through their regular practice of routine techniques and the acquisition of mental skills' (p. 217). The conception of the individual child rejects the idea of children working on the same task. In this conception children work individually to develop relational understanding. In the cooperative and collaborative conception, the emphasis lies on the interpersonal classroom that scaffolds children's learning. Lastly, the creation of a mathematically enriched classroom is manifested by posting mathematical material such as posters in and around the classroom to encourage individuality of expression. In several studies we found reports of mathematics teachers who focused on inquiry-oriented teaching (Towers, 2010). Towers (2010) found that many beginning mathematics teachers do not have a lot of inquiry experience in their own 'educational histories' (p. 259). Mathematics teachers who used inquiry-based materials enhanced student achievement and mathematical understanding, as well as attitude and motivation (Boaler, 1998; Hickey, Moore & Pellegrino, 2001).

In the present study we investigated the orientations toward teaching of in-service mathematics and science teachers. Following the findings of orientations toward teaching in both the science and mathematics education literature, we created a program where teachers had to think about teaching a lesson they thought needed improvement. Within this context we studied the teaching orientations of these teachers. Using a quantitative approach we

aimed to increase our understanding of teaching orientations of in-service teachers.

2.2. The context of the study

This study was conveyed in a professional development program called the mathematics and science partnership program. One of the goals of this program was to have teachers rethink the teaching of specific subject matter in their classroom to increase the performance of their students. The MSP program started with a two-week summer session. In the first week of the summer course, the teachers selected a topic that they wanted to teach the following year and wrote down their concerns about teaching this topic. They also wrote down their goals and purposes for their lessons. In the second week they attended presentations from university staff, had peer discussions about their teaching, and did literature research on the teaching of their topic. At the end of the second week they created a plan including the instructions they intended to use and justified how these instructions would help their teaching. The teachers were given time at the Summer Institute to reflect on their progress each day and to write down their reflections in a journal.

To study the orientations towards teaching of mathematics and science teachers, we investigated how the goals and purposes of teaching were related to the instructions the teachers intended to use in their plans. We used both the teachers' plans and their reflection report to study orientations towards teaching. By creating a more holistic view (Friedrichsen & Dana, 2005), we hoped to understand why science and mathematics teachers hold certain orientations and how these orientations drive their decisions on curricula, instructional strategies, and student assessment.

2.3. Method

2.3.1. Research question

The central question in 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 mixed-methods sequential explanatory design (Creswell, Plano Clark, Gutmann, & Hanson, 2003) to study the orientations to teaching of both mathematics and science teachers. This design is characterized by the collection and analysis of quantitative data followed by the collection and analysis of qualitative data within a single study. The rationale for using this design is the idea that neither quantitative nor qualitative methods are sufficient, by themselves, to capture the understanding of orientations towards teaching. However, in combination, quantitative and qualitative methods complement each other and allow for a more robust analysis, taking advantage of both their strengths. In our study we used this design in two phases. In the first phase, we collected and analyzed the quantitative (numeric) data. Then we collected and analyzed the qualitative (text) data to further understand the quantitative results obtained in the first phase (Steckler, McLeroy, Goodman, Bird, & McCormick, 1992). The results of this study are a product of both methods.

2.3.2. Participants

All of the 107 in-service math and science teachers who participated in the three cohorts of the MSP were included in this study. Fifty-four science teachers and fifty-three math teachers were included. The average years of teaching experience was 12.9 (SD = 9.1). The teachers were all located in schools in the Mid West of Illinois. All schools participating in this program had to comply with the learning and teaching standards of the Illinois State Board of Education. All teachers participated in the two-week Summer Institute described above. Teachers who relocated to another school out of the area after the Summer Institute were not included in the study, because they were not able to complete their classroom project.

2.3.3. Data collection

During a two-week Summer Institute the teachers completed an action research plan to improve the teaching of a selected science or mathematics topic. Each teacher could choose his or her own topic for an action research classroom project. In their plans, the teachers wrote down their teaching goals and their purposes for teaching this topic and explained why they focused on these goals and purposes. They also included the instructional strategies they intended to use to reach their teaching goals. We used the teachers' plans and their reflective journals as our data to study the teaching orientations of the participants.

2.3.4. Data analysis

Following a sequential explanatory design , we first collected the teachers' statements from their teaching plans concerning their beliefs and knowledge of the goals and purposes of their teaching as well as the instructions they intended to use in their teaching. We used an open coding approach (Corbin & Strauss, 2003) to code the different statements. We first coded the goals and purposes of their teaching and then coded the nature of the instructions they intended to use to serve those purposes.

Two independent researchers coded the statements of the teachers. To develop a category system to code all data, both authors independently labelled the statements of twelve randomly selected teachers. In an open coding process, data saturation, where no additional codes emerge, is usually reached after twelve participants (Guest, Bunce, & Johnson 2006). Next, the two researchers discussed the codes found and decided which codes to use in the study. Codes with similar content were merged into one code. Then the researchers coded the remaining data of the 95 teachers. An inter-rater reliability (Cohen's kappa) was calculated for the codes on both purposes and goals, and intended strategies (see table 2.2.).

For the purposes and goals, the following codes were used:

Table 2.2.

Codes for purposes, goals and intended strategies

Variables	Explanation
Purposes and goals ^a	
P1: content	focus on content with the purpose of increasing students' content knowledge of math or science
P2: skills	focus on skills with the purpose of developing students' process skills in math or science
P3: inquiry	focus on inquiry with the purpose of developing inquiry skills in math or science
P4: motivation	focus on student's motivation with the purpose of increasing students' interest in learning math and science
Intended strategies ^b	
S1: lecture	use of didactic approaches such as direct teaching, lectures and classroom demonstrations
S2: hands-on	use of hands-on activities, such as drawing, cut and paste, computer assignments, internet, game boards etc
S3: experiments	use of classroom or lab experiments
S4: projects	use of inquiry-based projects such as projects and project investigations etc

Note. a: Cohen's kappa = .87; b: Cohen's kappa = .91

After we coded all the data, we determined the frequencies of the codes for the goals and the intended (or preferred) instructional strategies for each teacher. These frequencies were used as quantitative data for statistical analyses. To study possible relationships between the teachers' goals and their preferred instructional strategies, we used two types of statistical analyses for this study. First, we used hierarchical cluster analysis (HCA) on the whole group of teachers to explore whether they could be divided into homogenous subgroups (so-called clusters). HCA divides teachers into various groups based on distinctive characteristics or patterns, which in this

case refer to the teachers' goals and their intended instructional strategies. Teachers' membership of a cluster was determined by using HCA to label the participating teachers (Van Driel, Verloop, Van Werven, & Dekkers, 1997) and to determine the clusters consisting of homogenous subgroups with similar patterns. Second, we used an exploratory technique, PRINCALS, to explore the possible relationship between the teaching goals and the instructional strategies. PRINCALS is essentially the same as Principal Component Analyses, with the difference that PRINCALS allows categorical data to be explored (De Heus, Van der Leeden, & Ganzendam, 1995). PRINCALS allows data to be plotted in an n-dimensional manifold, where the underlying structure of both objects (teachers) and variables (goals and intended strategies) in relation to each other is revealed in a biplot (Van Driel et al., 1997). A biplot is a two- or three-dimensional image where objects (teachers) are represented by points, and variables (goals and intended instructional strategies) as vectors (Gifi, 1990, p. 191). When the points are closely situated to each other, this indicates that the teachers may have similar orientations. Vectors pointing in the same direction indicate a stronger relationships between the variables they represent. The position of a point with respect to a certain vector indicates how a teacher's orientation is related to a certain goal or instructional strategy. Using HCA in combination with the PRINCALS manifold resulted in cluster areas of teachers with similar orientations. A 'cluster area' can be defined as a place in the biplot where the points (teachers) belonging to a particular cluster are displayed (Van der Rijst, 2009).

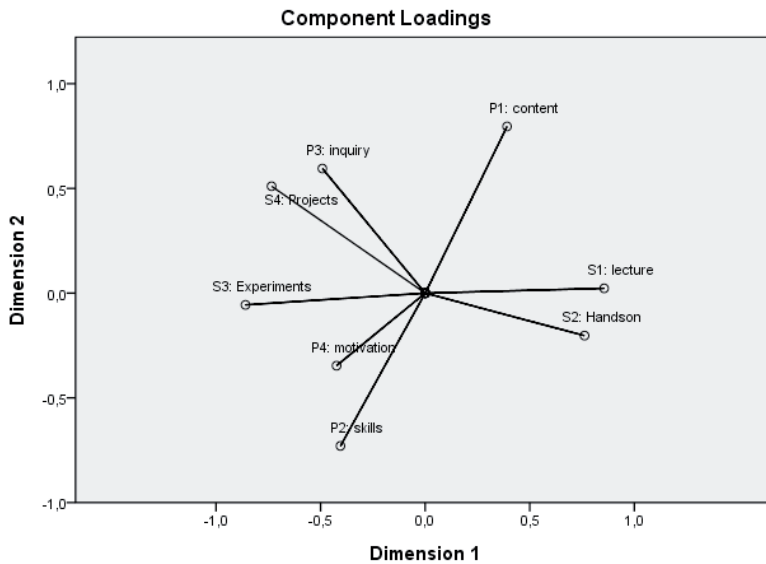
2.4. Results

Using PRINCALS we found two dimensions that accounted for 66 % of the variation of the data. PRINCALS, also generated a table with the component loadings of all the variables (the goals and the instructional strategies) on these two dimensions (see Table 2.3). From this table, PRINCALS used the coordinates of each variable to generate a two-dimensional plot showing the goals and instructional strategies in graphic form (see Figure 2.1).

Table 2.3.

The loadings of the purposes of teaching (P) and the intended instructional strategies (S), on two dimensions

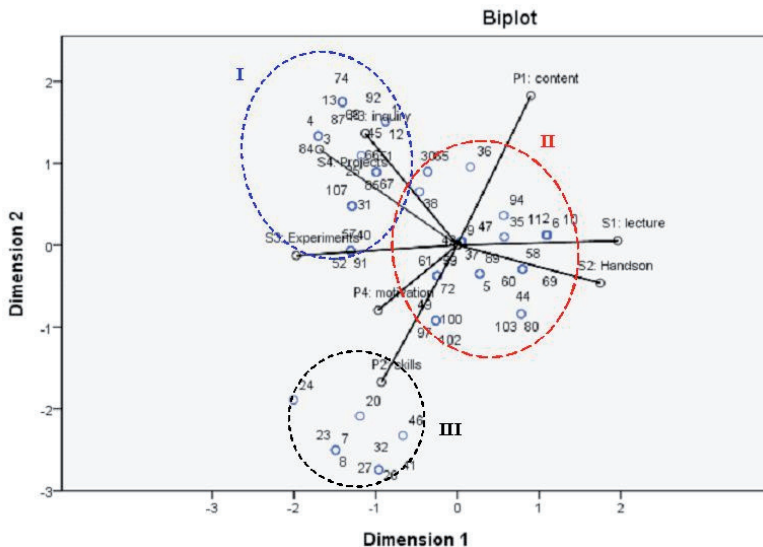
Variables	Dimension	
	1	2
P1: content	.392	.796
P2: skills	-.45	-.730
P3: inquiry	-.491	.595
P4: motivation	-.424	-.346
S1: lecture	.856	.023
S2: hands-on	.762	-.203
S3: experiments	-.859	-.056
S4: projects	-.734	.510



Variable Principal Normalization.

Figure 2.1. Graph of the purposes of teaching (P) and the intended instructional strategies (S), explained in two dimensions.

The vectors of the eight variables that represent the teachers' orientations are also plotted on both dimensions in Figure 2.1. The teachers' intended instructional strategies are best explained by dimension 1. The teachers' intended instructional strategies 'experiments' and 'project work' are found on the left part of this dimension, whereas 'lecture' and 'hands-on' are positioned on the right part. From this dimension we interpreted that the left part predominantly explained student-regulated strategies, whereas the right part explained the use of teacher-regulated strategies. Although hands-on can be seen as a student-centered strategy, we interpreted it to be regulated by the teachers in the classroom, which is why it is found on the right part of the plot (see Figure 2.1). This means that although students were actively involved in the hands-on activities, these activities were selected and regulated by their teachers. We believe that dimension 2 explains the position of the teachers' goals: 'teach content knowledge' and 'teach inquiry' are positioned in the upper part, whereas 'teach skills' and 'motivate students' are found on the lower part of dimension 2.



Note. I, II, III are clusters with different main orientations.

1, 2, 3, etc. are the teachers in the study.

Figure 2.2. Dispersal of teachers belonging to a main orientation achieved by using PRINCALS and HCA.

Using both HCA and PRINCALS, to locate subgroups of teachers in the two-dimensional space, we found three main clusters representing three main orientations. Figure 2.2 shows that cluster I is low in dimension 1 and high in dimension 2, which indicates that teachers in this cluster focused on learning science or math using student-regulated activities. Cluster II is high in dimension 1, which indicates that these teachers were mostly using teacher-regulated activities. No real preference was found in their goals, indicating that they were both interested in teaching math or science content, and also how to do math or science. Cluster III is low in both dimensions indicating that their focus was on doing science or math using student-regulated activities. HCA provided three homogenous groups (see dotted circles in Figure 2.2) of teachers with similar scores on both variables, which we identified as three main orientations:

- I. Content-driven with student-oriented activities.
- II. Content-driven with teacher-oriented activities.
- III. Skills-driven with student-oriented activities.

Within each cluster, we also found subgroups of teachers with particular emphases in their orientation. We elaborate on these orientations using teachers' data to explain each group.

Orientation I: Content-driven with student-oriented activities.

Seventeen science teachers and three math teachers were included in this group. These teachers had the same orientation: to teach content knowledge using experiments or classroom project designs. Their main focus was on teaching content knowledge. Within this cluster we saw, however, that teachers had different emphases in their orientation. Some teachers intended to teach inquiry for the students to learn the content, whereas others intended to focus more on experiments. These emphases appeared to emerge from different concerns resulting in multiple goals. The following is an example of a teacher who wanted to teach her students science content and to teach inquiry: *'I want to see improvements in my students' knowledge about Shawnee National Forest Issues and some possible solutions*

to these issues. The problem is that my students are not problem-solvers nor self-thinkers. My plan is to use inquiry-based learning. Inquiry-based learning will keep my students excited about learning while retaining the information.' (reflective journal of teacher 4). Teacher 4 was concerned that since her students were not problem-solvers, they therefore lacked content knowledge. This was different, however, for the next teacher we found in the same cluster: *'I have noticed that students may do well on chapter tests, but when I refer back to the material later in the year, there is no retention of the material. My guess is there was never any real depth of understanding. To increase that depth, I think hands-on, minds-on materials will help in addition to not teaching as many topics and slowing down. Another problem I have is I think my lack of enthusiasm for science transfers to my students. By having them do experiments and observations, their enthusiasm and motivation to retain the knowledge will grow together.'* (reflective journal of teacher 91). Teacher 91 was concerned about her students' lack of content knowledge because they could not apply their previous knowledge as they proceeded in the curriculum. We found teachers who had the same main orientations but their additional goals 'learn inquiry to retain knowledge' (teacher 4) or 'motivate students to engage in experiments to retain knowledge' (teacher 91) resulted in different emphases in their orientations. Figure 2.2 shows teacher 4 in the upper part of cluster I, while teacher 91 is positioned at the lower part of this cluster.

Orientation II: Content-driven using teacher-regulated activities.

Twenty-eight science teachers and forty-six math teachers were found in this group. These teachers intended to teach math or science content using classroom lectures and supplementing these lectures with hands-on activities. From their plans we found that these hands-on activities were all teacher-regulated. In their plans, the teachers also stated that they were concerned about students' poor knowledge of the math or science topic and students having difficulties understanding the concepts related to this topic. These

teachers stated that (teacher-regulated) hands-on activities should increase students' knowledge. The teachers intended to use classroom material that would support their lectures. We also found teachers with different emphases in this orientation. Some teachers intended to have students learn science or math by introducing classroom discussions, which were led by the teachers. They believed that when students are more involved, they are more willing to learn science or math. Example: *'In my enhanced lessons the focus shifts from that of the conventional classroom through use of discussion, questioning, and requests for pupils to explain their ideas, conjectures, and reasoning.'* (reflective journal of teacher 30). Other teachers with a different emphasis were those who focused solely on teaching math or science concepts using lectures and hands-on activities. Example of a math teacher: *'I think geometry works best when it is hands-on. With the use of technology, students will be able to better visualize the concepts.'*(reflective journal of teacher 2). Another teacher stated that students had a hard time understanding the concepts because they lacked visualization capabilities. This teacher believed that if the students could visualize concepts or processes they would be able to understand these concepts and processes. Example: *'I plan to use the digital projector to introduce each of the sections of geometry. The students will be able to visualize and experience concepts that have been very difficult to get across using a chalkboard. Geometry has been a low point of understanding for 7th grade students for a long time. I think the use of the digital projector would be a definite help.'* (reflective journal of teacher 10). Another variation was the emphasis on teaching math or science skills together with content using hands-on activities: *'I want my students to work with more 'hands-on' type materials and technology to improve their retention of geometry skills. I feel this would help them retain more geometry if they can physically manipulate the media being used.'* (reflective journal of teacher 49). Some other teachers had a different emphasis based on an additional goal: to motivate students to learn science or math. They believed that when students are motivated, they are more willing to learn science or mathematics content knowledge. Example: *'I am wanting to get the students involved and excited about Earth*

Science. By introducing new things to the students, they will increase their enthusiasm for learning science in the classroom.' (reflective journal of teacher 65).

Orientation III: Skills-driven using experiments.

Four math teachers and nine science teachers formed cluster III. This third group of teachers differed from the first two groups because their orientation was mainly focused on teaching mathematical or science skills. They believed that experiments are good strategies to increase those skills. Their concern was not so much on what students need *to know about math or science*, but more on *doing math or science* (cf. Hodson, 1992). Their concerns were primarily focused on the fact that their students had poor skills in math or science. They believed that students can achieve more and better when they have the necessary process skills: *'I wanted my students to have more skills to apply scientific concepts to the real world to make science relevant to them. I wanted the students to be able to collect data and organize it to be relevant to conduct research... I was able to teach the necessary skills for using microscopes that will hopefully carry over into other areas of science education. Also, I was able to teach them how to conduct experiments through an investigation of a 'crime scene.'* (reflective journal of teacher 32). Another teacher intended to use experiments to teach students about using graphs: *'I need to provide students with a greater diversity of experiences with using graphs in Biology I.'* (reflective journal of teacher 7). In this group of teachers we found no meaningful variation in their orientation, that is, they all had the same emphasis in their orientation: to teach skills.

2.5. Conclusions and discussion

From the literature we found that there is ambiguity about teaching orientations. Teaching orientations are not only described as 'knowledge and beliefs about the purposes and goals' (Grossman, 1990; Magnusson et al., 1999) but also as 'general views about teaching' (Anderson & Smith,

1987; Magnusson et al., 1999). It is because teachers' beliefs are hard to define, that orientations are still messy constructs (Friedrichsen & Dana, 2005; Friedrichsen et al., 2011). In our study, we found that to gain a better understanding of teachers' orientations, it was not sufficient to only determine their knowledge and beliefs about goals and purposes, but it was also imperative to study the intended strategies that served their goals (Magnusson et al., 1999). We found that each teacher had different goals and specific intentions of using instructional activities that lead to specific orientations. However, when analyzing these different goals and intended instructional strategies, we were able to cluster these orientations into three distinct teaching orientations: content-driven with student-oriented activities, content-driven with teacher-oriented activities, and skills-driven with student-oriented activities. Within each of these main orientations we found that the teachers' individual orientations differed. These differences relied on the emphasis found within the orientation based on additional goals or beliefs of the teacher. Earlier studies on teachers' orientations have mentioned that in-service biology teachers' orientations differ because they hold multiple goals referred to as main goals and peripheral goals (Friedrichsen & Dana 2003, 2005). Friedrichsen & Dana (2005) noted that both the main goals and peripheral goals must be taken into consideration when investigating teaching orientations. These studies were conducted on a small number of teachers and they did not mention any similarities or differences between the orientations. We do however support their statement that teachers' orientations contain multiple goals.

We found the Hodson goals (1992) to be important when studying teaching orientations. In our study we found similar goals in different perspectives. The first goal we encountered was *learning science or mathematics content*, which was one of the Hodson's science goals. Hodson's second science goal, *doing science*, was divided into two separate goals in our study: *doing science or mathematics*, which involved learning basic skills, such as 'microscopy' in science; and 'balancing equations' in mathematics and *inquiry*, which

involved students following the steps of doing scientific or mathematical inquiry. We did not encounter the Hodson's third goal : *learning about science*. However, we did find a fourth goal: *motivating students to become interested in science or mathematics*. This goal was mentioned by 27 teachers as an important goal and was therefore included as a separate goal in this study. We found teachers with this goal in all three clusters. We believe that when investigating teaching goals, the science goals mentioned by Hodson (1992) as well as 'motivating students to become interested in science or mathematics' should be considered as important goals in future research.

2.5.1. Motivation

Figure 2.1 shows that learning science or math *content* is mostly explained in the upper part, where as *doing* science or math is explained in the lower part. Inquiry as a goal is seen here as part of learning science or math content. Motivation, however, is found between the clusters (see Figure 2.2), meaning that all the clusters had teachers who had motivation as an additional goal. Talanquer et al. (2010) identified 'motivating students' as a separate orientation. In our study, we found that 'motivating students' was not a separate orientation but more a teaching goal. This goal was usually found in combination with another goal leading to different emphases of the orientation. For example, where one teacher responded that she intended to motivate her students to learn specific science concepts (cluster I), another responded that she needed to motivate the students to practice skills to be used in their daily lives (cluster III). Magnusson et al. (1999) did not mention any orientation or goal that relates to students' motivation, but this goal seemed to be an important goal in teachers' orientations towards teaching science or mathematics in our study.

When comparing the orientations of the mathematics and the science teachers, we found that the content-driven orientation with student-oriented activities was dominated by the science teachers. When investigating goals of teachers, we found that inquiry as a goal was mostly found with the science

teachers and less with the mathematics teachers. It seems that although mathematics teachers are becoming more inquiry-minded, it is not as common as an inquiry orientation in science teaching. Although research has shown that mathematics educators and researchers have pleaded for more student-oriented activities such as inquiry, the majority of the mathematics teachers in this sample still firmly believed in traditional teaching (Towers, 2010; Jacobs et al., 2006; Stigler & Hiebert, 2004). Although we found a majority of 46 mathematics teachers who used teacher-centered activities (cluster II), we also found 3 mathematics teachers who engaged in inquiry (cluster I) and 4 math teachers who used student-centered activities to practice skills (cluster III).

2.5.2. The Magnusson et al. (1999) orientations

Magnusson et al. (1999) presented nine different orientations distilled from the science education literature. While some scholars have used these orientations in their studies, other researchers have argued that, in practice, teachers do not hold one single orientation, but have multiple orientations (Friedrichsen & Dana, 2005). Friedrichsen and Dana (2005) mentioned that because teachers hold multiple goals they have different orientations. In our study we found that teachers did indeed have multiple goals and multiple strategies which resulted in a complex orientation. However, Magnusson et al.'s (1999) orientations can be traced in our study. Examining the orientations 'academic rigor' and 'didactics' more closely, Magnusson et al. (1999) referred to these orientations as focused on transferring content knowledge. In our study these orientations would be considered content-driven using a teacher-oriented approach (cluster II), while Magnusson et al.'s (1999). orientation 'discovery' may be considered content-driven with a student-centered approach (cluster I). The Magnusson et al. (1999) orientations have been used in plenty of other studies, but empirical studies such as this one are needed to retest and re-examine them. Revisiting these orientations in empirical studies could provide them with clear and complete descriptions making them fit for future research.

2.5.3. Mathematics orientations

Thompson et al. (1994) presented two main orientations: conceptual orientations and calculational orientations. Both of their orientations reflect the main orientations found in this study: content-driven and skills-driven. Thompson et al. (1994) explain the conceptual orientations as the way a teacher acts to 'develop conceptual understanding' with students. This 'development of conceptual understanding' is found in our study as a content-driven orientation. However, we did make a distinction in that teachers can focus on content with either the intention of teaching this content in a teacher-centered way or in a student-centered way. On the other hand, the calculational orientations of Thompson et al. (1994) involve the skills that produce results, that is being able to do mathematics. In our study, this orientation mostly resembled our skills-driven orientation. Other orientations found in the mathematics literature can also be traced in our study. From the five conceptions of secondary mathematics teachers found in the study of Andrews and Hatch (1999), two conceptions resemble the orientations in our study. Their process orientation contains an understanding of students understanding their own concepts, and thus relates to content knowledge, whereas another of their mathematical conceptions involves a skills orientation, which is similar to our skills-driven orientation. The other three orientations in the Andrews and Hatch (1999) study focus on individual learning, collaborative/cooperative learning, and on classroom orientation. In our study we did not find explicit orientations where teachers were concerned about individual or group learning nor an orientation on the classroom.

2.6. Implications

2.6.1. Implications for professional development

When planning professional development programs aiming to improve science or mathematics teaching, it is important to consider teaching orientations. Determining teaching orientations may be complex, but

these orientations play an important role in teachers' pedagogical content knowledge. When investigating teachers' PCK in a professional development program, it is important to understand the teachers' orientations and why they have these orientations. During the PD program, teacher educators can influence the orientations in order to help 'shape' other PCK components. If teacher educators want to influence science teachers' PCK, therefore, it may be helpful to understand the science teaching orientations of the teachers. Teacher educators may want to study the teachers' lesson plans to determine what goals and intended instructional strategies the teachers have to understand their orientations to teaching.

2.6.2. Implications for future research

We recommend more empirical studies on teaching orientations for mathematics and science teachers. It is imperative to investigate teaching orientations using a broader perspective than just the definition used by Magnusson et al. (1999). While Magnusson et al. (1999) took into consideration teachers' 'knowledge and beliefs of goals and purposes of science teaching'(p. 97) to describe their science teaching orientations, they also stated that: 'it is not the use of a particular strategy but the *purpose* of employing it that distinguishes a teacher's orientation to teaching science' (p. 97). In our study we took into consideration the teachers' goals and purposes of teaching math or science as well as their knowledge and beliefs about science and mathematics teaching strategies. Empirical studies are needed to determine whether more factors, other than the goals and instructional strategies, are important to understanding orientations to teaching. In a recent article, Friedrichsen et al. (2011) urged that the nature of science be taken into consideration. They also suggested investigating the relations between teaching orientations and other PCK components. Knowledge about the curriculum and knowledge of assessment are also important features in the PCK development as well as the teachers' knowledge about students' learning.

We also suggest that there is a need for in-depth empirical investigation of teachers' main orientations rather than only focusing on the single orientations found in the Magnusson et al. (1999) study. Main orientations refer to general orientations. These general orientations can be concretized into teachers' individual orientations based on their particular emphases. To understand these particular emphases in science teaching orientations, it is imperative to study the teachers' additional goals and their intended instructional strategies. Furthermore, it is also important to study how these orientations 'shape' the other PCK components.