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

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Chapter 5. The relation between teachers' orientations towards science teaching, teaching concerns, levels of inquiry-based instructions, and their classroom activities

Abstract

A group of 24 science teachers were studied to investigate the relationships between teachers' orientations towards science teaching, teaching concerns, and their levels of inquiry-based instructions. We used a qualitative approach to study these relationships. We found that when science teachers planned to use inquiry-based instructions at lower levels such as 'confirmation' and 'structured inquiry', they were mostly concerned about their students' low grades, their lack of science knowledge, and their lack of inquiry skills. When science teachers planned to use inquiry-based instructions at higher levels such as 'guided inquiry' and 'open inquiry', we found that they were still concerned about the weak relation between students' inquiry skills and their inquiry experiences of the real world. When studying the teachers' orientations, we concluded that teachers who engaged in lower levels of inquiry mostly had teacher-centered orientations, while teacher who engaged in higher levels of inquiry mostly expressed student centered orientations.

Keywords: inquiry, science teaching orientations, concerns.

5.1. Introduction

The use of inquiry-based instructional methods in the science classroom has been widely advocated in the past decade from a variety of sources, including the American Association for the Advancement of Science (AAAS, 1993) and the National Research Council (NRC, 1996). Inquiry-based learning tends not only to help students to develop content knowledge, but also to teach them what science is and how it is done (Sanger, 2007). From a teacher's standpoint, it is important to know how science can be taught through inquiry, and how students learn science when it is taught that way (NSTA, 2000). With inquiry-based learning, students engage in scientific investigations and problem-solving. In addition to general problems such as time constraints, limited classroom facilities, and complex class schedules, the implementation of inquiry lessons is also influenced by various important factors (Roehrig & Luft, 2004). These include the teachers' understanding of science concepts (Hashweh, 1987), the complex processes of teaching and learning and the nature of science (Duschl, 1988), and teachers' beliefs about science teaching and learning (Pajares, 1992). Magnusson et al. (1999) argued that teachers' orientations towards science teaching filter teachers' decisions about implementing inquiry in their classrooms (Magnusson et al., 1999). Some studies have linked teachers' beliefs to their inquiry lessons (Crawford, 2007), but so far none have focused on teachers' orientations towards science teaching and their inquiry lessons. To understand how, and why, science teachers construct inquiry lessons in their practice, we investigated experienced science teachers' orientations towards science teaching in relation to their ways of implementing inquiry teaching. Since in-service teachers take into account their experience from previous years of teaching, we also investigated their concerns, and the potential obstacles they perceived when implementing inquiry teaching.

The aim of this research was to gain a deeper understanding of science teachers' inquiry lessons and how their orientations towards science teaching

interacted with their classroom decisions. For this purpose, we focused on a group of science teachers who planned and conducted inquiry-based lessons in their classrooms in the context of a professional development program.

5.2. Theoretical framework

5.2.1. Science inquiry

In several studies, Crawford and others have explored the complex nature of teaching science inquiry in schools (Crawford, 1999; 2000; 2007; Crawford, Zembal-Saul, Munford, & Friedrichsen, 2005). Crawford (1999) found that novice teachers are too inexperienced to create inquiry-based instructions due to their lack of content knowledge, pedagogical knowledge, and pedagogical content knowledge. She noted that 'there is a paucity of research on how to design instructional environments to promote students' understanding of science inquiry' (Crawford, 2000, p. 917). She concluded that teachers should be knowledgeable in not only engaging students in hands-on activities, but also in engaging 'students in cognitive processes used by scientists, when asking questions, making hypotheses, designing investigations, grappling with data, drawing inferences, redesigning investigations, and building and revisiting theories' (p. 934). In a more recent study, Crawford (2007) acknowledged that despite a professional development school setting aiming to teach science as inquiry, prospective teachers practiced teaching strategies that ranged from traditional teaching to full-inquiry projects.

Even if teachers engage in inquiry-based teaching, not all inquiry activities are equivalent (Bell et al., 2005). Inquiry-based activities can range from highly teacher-directed to highly student-oriented. Bell et al. (2005) proposed a four-level model of inquiry (see Figure 5.1). Level 1 is called 'confirmation inquiry' where the teacher provides a research question to which the students know the answer in advance. Students are thus confirming what is already known. In level 2, structured inquiry, the research question is also provided,

but the students do not know the answer in advance. However, the students are provided with a set of prescribed procedures. In level 3, guided inquiry, it is the teacher, again, who poses a research question, but the students devise their own methods to answer this research question. Level 4 is called open inquiry, where the students are responsible for creating their own research question and their research design for answering this question.

		How much information is given to the student?			
	Level of inquiry	Question?	Methods?	Solution?	Inquiry based activities
1	Confirmation	x	x	x	Highly teacher directed
2	Structured	x	x		
3	Guided	x			
4	Open				Highly student directed

Figure 5.1. Four-Level Model of Inquiry (adapted from Bell, Smetana, & Binns, 2005)

5.2.2 Orientations towards teaching science

Various scholars have argued that orientations towards teaching science should be seen as knowledge and beliefs that guide instructional decisions in the classroom (Borko &Putnam, 1996; Magnusson et al., 1999). In particular, science teachers' beliefs influence the inquiry activities they use in their science lessons (Crawford, 2000, 2007). No research, however, has shown evidence how these orientations actually guide the planning and conducting of classroom instructions. Magnusson et al. (1999) stated that 'the orientations are generally organized according to the emphasis of the instruction, from purely process or content to those that emphasize both and fit the national standard of being inquiry-based.' (p. 97). These scholars proposed nine different orientations ranging from a process orientation (process) to content (academic rigor, didactic, conceptual change), to both

(activity-driven, discovery, project-based science, inquiry, guided inquiry) (see Table 2.1). Magnuson et al. (1999) elucidated that these teaching orientations are based on teachers' purposes and goals for teaching science (p. 97).

Friedrichsen and Dana (2005) studied these orientations empirically and concluded that science teachers hold science-specific orientations as well as general orientations. In their study they evidenced that biology teachers have both central and peripheral teaching goals. They concluded that orientations consist of three major goals: (1) affective domain goals; (2) general schooling goals; and (3) subject matter goals. They noted that in addition to the teachers' orientations, prior work experience appeared to be an important factor influencing preparation for teaching. Tsur and Crawford (2001) also noted that teachers held more than one orientation with one or two primary orientations. Examining these orientations closely, we found that they include the purposes of science teaching (Magnusson et al., 1999). Friedrichsen et al. (2011) re-examined the science teaching orientations and concluded that this concept is problematic because (a) orientations are used in different or unclear ways; (b) there is an absent or unclear relationship between the teaching orientations and the other PCK components; (c) teachers cannot simply be assigned to one of the nine categories of Magnusson et al. (1999) orientations; and (d) the overarching function of this component is ignored in the literature. They propose defining science teaching orientations as a set of beliefs using the following dimensions: goals and purposes of science teaching, views of science, and beliefs about science teaching and learning.

5.2.3. Science teaching concerns

Teachers' knowledge plays an important role in the preparation, implementation and evaluation of lessons. Awareness of obstacles in learning is also part of the teachers' knowledge which they take into consideration when planning and conducting science lessons. De Jong and Van Driel (1999) found that as teachers teach, they learn more about the obstacles of teaching. Earlier studies on teachers' concerns have shown that prospective teachers

have other concerns than in-service experienced teachers (Melnick & Meister, 2008). In-service experienced teachers have concerns and orientations that are closely related to their prior work experiences (Friedrichsen & Dana, 2005). De Jong and Van Driel (1999) reported that prospective teachers have three different pedagogical content concerns (PCC): self PCC, task PCC, and student PCC (cf. Fuller & Brown, 1975), where one PCC may be dominant over the others (De Jong, 2000). Berry et al. (2008) asked in-service science teachers to start from their own science teaching concerns when they investigated teachers' pedagogical content knowledge (PCK). They found that teachers were concerned about students' learning when they planned their lessons. In this study we also focused on the teachers' concerns when they planned their inquiry-based lessons.

5.3. Context of the study

The present study was conducted in the context of a professional development program called the mathematics and science partnership program in the year 2006-2007. One of the goals of the MSP was to increase teachers' performance when teaching mathematics or science. A specific aim of the MSP program was to increase teachers' knowledge of teaching science and mathematics through inquiry. In this study we only investigated the science teachers who participated in the MSP program of 2006-2007 in the South West region of Illinois. The teachers were asked to conduct inquiry lessons in their class. As part of the MSP, teachers were asked to use an action research approach to develop and conduct their inquiry-based lessons. In this way they could systematically monitor their own progress. Applying this approach, the teachers were required to plan their lessons, conduct their lessons, collect data for their action research, write a progress report, and keep a journal of their reflections. To start the program, a two-week Summer Institute was organized during which the science teachers were exposed to scientific inquiry. In the first week of the Summer Institute, university staff taught them about scientific inquiry, explaining the different steps of

scientific inquiry. The university staff posed a problem on ecology and the science teachers had to create their own questions. Discussions were used to help the teachers to focus on these questions on ecological relationships. Next, the university staff facilitated the teachers in an outdoor activity where the teachers could design how to collect data on different plants and invertebrates in the neighbourhood. They then had to analyze their data and explain the ecological relations based on analyses of the data collected. Each group had to present their findings to other groups, including how they answered their questions. In the second week, the teachers were required to conduct a literature review on inquiry-based teaching. They could discuss and share their findings with other teachers, and the university staff acted as mentors for in-depth questions on inquiry-based learning. After the Summer Institute the teachers created lesson plans using scientific inquiry as the basis for lessons on science topics of their own choice. Throughout the entire year, each teacher worked on a progress report, which was part of their action research. All the teachers kept an electronic journal to reflect on their lessons.

5.4. Method

5.4.1. Aim and research questions

Our aim was to gain a better understanding of how and why teachers conduct inquiry-based lessons. In particular, we were interested in how teachers' orientations, their concerns and other variables, such as years of teaching experience and grade level, were linked to their inquiry-based teaching in the context of a PD program (i.e., the MSP). We investigated teachers' orientations towards science teaching and their teaching concerns in relation to how they planned and conducted their inquiry-based lessons. The main question which guided this study was: *What is the relation between teachers' concerns, their orientations towards science teaching, and the instructional levels of inquiry when they design and conduct lessons?* This main question consisted of the following specific sub-questions:

1. What level of inquiry do science teachers use when planning inquiry-based lessons?
2. How are the teachers' concerns and their orientations towards science teaching related to their levels of inquiry?

5.4.2. Data collection

Twenty four in-service science teachers participated in the MSP program of 2006-2007 and were included in this study. Throughout the entire year these teachers documented the progress of their action research. A pre-formatted document was used to make sure that the teachers documented all the different steps of their action research in the progress report, in which they had to provide a rich description about why the teaching of this topic had been a problem in previous years. The teachers included their purposes and goals for teaching this topic as an inquiry lesson in the report. All the reports were collected at the end of the year. To study the teachers' planned activities, we also collected their lesson plans, in which they described the activities that they planned for their inquiry lessons. As a third data source we collected the teachers' reflective journals. We asked the teachers to write down their reflections in an electronic journal during the year. Three different data sources were therefore used for this study: the teachers progress reports, their reflective journals, and their lesson plans.

5.4.3. Data Analyses

To safeguard the objectivity of the data analyses, coding was carried out independently by two researchers and a research assistant over the whole analysis process. We read the data several times to become familiar with the various data sources and their content. We then decided what data to use from each of the data sources.

1. From the teachers' *progress reports* we selected general information such as years of teaching experience, students' grade level, number of students in the class and science topic taught. From these reports we also

selected statements teachers had made regarding their concerns and their orientations towards teaching. Statements regarding the teachers concerns usually started with: 'My students had difficulties with...', or 'My students don't have any experience in…' or 'Last year I had a hard time to...'. To code the teachers' concerns, data analysis aimed at identifying codes emerging from the data using a grounded theory approach (Glaser & Strauss, 1967). To determine the teachers' orientations, we used statements from the progress report starting with: 'My goal for this project is to…'or 'I want my students to …'. To study the science teachers' orientations we coded the statements using the nine orientations of Magnusson et al. (1999). From the data we found some statements that did not reflect the orientations of Magnusson et al. In that case we used additional codes for the teaching orientations that emerged from our data.

2. From the teachers' *lesson plans* we determined what level of inquiry was used following the model of Bell et al. (2005). When a teacher planned to use inquiry to confirm what was lectured or demonstrated in the classroom, this was labeled as level 1:confirmation. A teacher's inquiry level was labeled structured inquiry (level 2) when the teacher provided a research question and gave students the procedures to conduct inquiry. We labeled a statement as level 3 (guided inquiry) when a teacher posed the research question but had their students come up with their own method of inquiry. The teacher had to make sure that the students' inquiry plan would lead them to researching and answering their research questions. Level 4 (open inquiry) was coded when we found that the teacher only presented the science subject, and the students had to come up with their own research questions and plan and conduct their own inquiry.

After categorizing the statements with the different codes, we grouped the teachers according to the different levels of inquiry, that were assigned to them (see above). We then characterized each group by analyzing the

relations between the teachers' concerns and their orientations. We used a cross-case comparison to identify similarities and differences between the teachers. Yin (1994) noted that multiple case studies provide the researcher with greater opportunities to explore patterns and themes within the data, so we decided to treat each teacher as an individual case. 'Understanding unique cases can be deepened by comparative analysis' (Patton, 2002, p. 56). The process of comparing teachers' concerns and their orientations with the same level of inquiry across the case profiles allowed us to gain a deeper understanding of the data.

5.5. Results

We first created a spreadsheet with the codes used for statements found in the different data sources (see Appendix B). Based on this spreadsheet we created Table 5.2 with an overview of the results, where the teachers are grouped according to their level of inquiry.

We found eight teachers who engaged in confirmation inquiry, eight science teachers at the level of structured inquiry, six teachers at the level of guided inquiry, and two teachers at the level of open inquiry. Although we found that all teachers were oriented towards teaching content, different patterns occurred at each level of inquiry. All teachers were also oriented towards teaching skills, except those who engaged in confirmation inquiry. To explore the relationships between the teachers' concerns, their teaching orientations and the level of inquiry, we describe each group explaining the level of inquiry, the teachers' orientations, and their concerns. We illustrate each group using examples from the teachers' data.

Level 1: Confirmation inquiry

From analyzing the teachers' lesson plans, we identified a group of 8 teachers who were using inquiry to confirm what was already known. In their lesson plans we found that the teachers typically followed the sequence: explain

Table 5.2.
Overview of the science teachers' levels of inquiry, their concerns and their orientations

Level of inquiry	Confirmation (N = 8)	Structured (N = 8)	Guided inquiry (N = 6)	Open inquiry (N = 2)
CONCERNS				
Low test scores	X	X		
Lack of knowledge	X	X		
Lack of inquiry skills		X	X	
Lack of real world inquiry experience			X	X
TEACHING ORIENTATION				
Content-driven	X	X	X	X
Skill-driven		X	X	X
Activity-driven	X	X		
Didactic	X	X		
Academic rigor	X	X		
Inquiry			X	X
Discovery			X	X
Project-based			X	X

the science concept, then explain the scientific method, then provide a research question. Next, they selected an activity that aimed to assist the students to find answers to the research question. The traditional 'cook-book' method was often used to plan the lessons. In our exploration of the data we found that the teachers in this group were either concerned about the students' low grades or their lack of knowledge of a certain topic. This lack of knowledge was sometimes inferred from low grades in previous years. When exploring their orientations to teaching, we found that these orientations were focused on knowledge; teachers intended to use mainly didactic and hands-on approaches. In their progress reports, the teachers' purposes in engaging students in inquiry focused on the use of hands-on activities. However, when we explored the progress reports and their

reflective journals, we found that the teachers often engaged in lecturing and explaining certain science concepts before engaging students in hands-on activities. Here is an example of how we linked a teacher's orientation and his concerns to his inquiry lessons: Ben, a 5th grade science teacher wanted his lesson to be more student-centered: *'I have 19 low ability students in my class this year. I am unsure what lesson plan to use, therefore I don't quite know how I will use the inquiry-based approach. One of the units covered in our science curriculum has to do with ecology. I have never felt confident with the lesson because I never had a good activity to go with the lesson. I am hoping to gain more inquiry-based activities to use in this unit. I feel that if I use more 'hands-on, minds-on' activities and require the students to use science vocabulary words in discussions, the students will remember and explain how living organisms interact with each other and their environment.'(from Ben's reflective journal).* Ben simplified his lessons on inquiry and started to explain to his students about ecological disturbances, before actually exposing his class to an inquiry activity. This activity was very much based on 'cook-book' instructions, where the students had to merely follow the instructions to get to the answers: *'I drew and explained the ecosystem within a control area and disturbance area. I read books about types and compatibility of fish and plants and explained this to my students, I then made an aquatic habitat with various aquatic plants and animals and so my students were able to observe and explain the minor disturbances in that ecosystem….'(from Ben's progress report).* Ben's orientations towards science teaching was focused on the science content and based on didactics and hands-on activities. As we can see from this example, he used the confirmation level to teach his lessons on general ecology. He used the aquatic habitat as an activity, so the students could explain through this activity what disturbances are, and so that he could confirm that the students understood what he had explained in class.

Level 2: Structured inquiry

At this level, the teachers (n=8) started their lessons by explaining the scientific method to their students. Next, they introduced the topic and posed a research

question. The students were given clear instructions on how to answer the research questions. In some cases, they handed in their answer sheets and in other cases they were asked to share their findings in a group presentation. Regarding the teachers' concerns, we found that, like the previous group, the teachers were also concerned about students' low grades or lack of content knowledge. However, with this group, we found in addition that the teachers were also concerned about the students' lack of inquiry skills or their lack of knowledge of the scientific method. Concerning their teaching orientations, we found that these were geared towards didactic and hands-on approaches, which were similar to the instructional approaches of level 1. The planned activities were a sequence of lecture, demonstration, explanation of the scientific method, followed by hands-on activities to become familiar with the topic or a specific skill. This sequence was then followed by an inquiry activity geared towards answering a research question. The following is an example from Kathy, an 8th grade science teacher, who reflected on her lesson plans: *'My students need to be able to understand the process of scientific inquiry, in order to investigate questions, conduct experiments, solve problems and understand fundamental concepts, principles and interconnections of life sciences… I have planned to take students out into the field and introduce them to the concept of inquiry-based approach by giving them their freedom to investigate/explore the prairie land behind our school for a preset amount of time and when they return explain the 5E method of inquiry. From that method they will hopefully begin to realize they have some control over what they will learn not just what I will tell them to do.'(from Kathy's reflective journal)*. Kathy wanted her students to find out what the soil of a specific grassland biome would contain for the grassland to grow. From her research report we found that she structured her activities to ensure that her students got engaged in inquiry-based learning: *'I did an introduction to the soils located in a grassland biome… Students were allowed to reflect on the unit of soil and were put in small groups… Then I explained the correct method to collect a soil sample… Tools (hand trowel, bag for soil) were distributed to each group and each group of students was paired with a teacher… I allowed students to*

choose the area to gather soil samples… Students took photographs as they collected their soil samples… They collected soil samples per collection data instruction sheet… They were asked to reflect and predict what their samples would contain… They then engaged in a discussion of soil color, particles, organic matter, soil creatures, and texture. Students then completed their soil texture experiment…' (from Kathy's research report). Kathy's orientation was skill-driven, aiming to let the students gain some experience in inquiry. Kathy used the structured inquiry approach in her lessons: She introduced the concept and gave them the assignments. She showed them the procedure for doing an inquiry by teaching the students how to collect and analyze soil samples.

Level 3: Guided inquiry

Teachers at the guided inquiry level (n=6), structured their lesson plans so that they posed the problem and stated the question based on their science topic. They asked their students to find a solution to this problem. We found that these teachers' concerns were focused on students' limited life experiences: lack of real life inquiry experience, lack of interest in science, or failure to connect science to the real world. Examining their orientations, we found them to be focused on the process of inquiry learning. Both discovery learning and project work were two major themes in their orientations towards science teaching. These teachers tended to pose a problem and questions to be answered. The students then began to work on a plan on how to answer these questions. The teachers had the role of supervising or facilitating the students. The activities were inquiry-based aiming to get the students to investigate the problem. We give the following example of Bertha, a fifth grade science teacher. Her purpose in these lessons was to get her students to engage in more inquiry-related learning: *'I would like for students to engage in inquiry-based lessons to help them learn about ecosystems.' (from Bertha's research report).* Bertha started her lessons by posing problems about ecosystems and provided a question*: 'I began my lesson by asking my students why we don't have wildlife habitat in our area…*

then I provided them questions about habitats in the area… I let my students decide how they wanted to answer the questions… One of the groups wanted to go on the internet to research habitats in the area and so I let them go on the internet for 45 minutes each day, making sure that they discussed their findings after each session' (from the reflective journal). Bertha also let other groups decide about their approach. When one group decided to go to the zoo, Bertha suggested a field trip to the zoo to her students: *'my students decided to observe fish in an aquarium to investigate aquatic habitats in the zoo, so they took a trip to the zoo…' (from Bertha's progress report) .* Bertha gave students time to collect and analyze their data about aquatic habitats. To evaluate their projects, Bertha asked her students to share their results: *'Upon return from the field trip, students were allowed time to work in their groups to make small presentations about their habitat findings. They decided to make charts or posters about their findings. Some students used pictures from the internet, while others used photos they had taken at the zoo. The presentations were evaluated by me, based on presentation of habitat materials and overall participation in the group (from Bertha's reflective journal)*. Bertha's orientation toward teaching was content and inquiry-driven using a project-based approach. Her level of inquiry was guided. Although she intended her students to do inquiry, she gave them 'guided' questions to research. She stimulated the use of inquiry activities to have her students gain an authentic inquiry experience in the field.

Level 4: Open inquiry

We found only two teachers who planned to use an open inquiry approach in their lesson plans. These teachers applied similar inquiry activities in their lesson plans as level 3 teachers. However, the difference with the previous groups is that these teachers did not pose research questions to the students. In both cases, the teachers introduced the topic and encouraged the students to come up with questions for research. After the students posed several questions, the teacher held a classroom discussion on what questions were worth investigating and the students were divided into

groups to start working on a research plan. Examples: *'Students ask their own 'real' questions, they took ownership in their project and were motivated to learn' (from Lila's progress report). 'Since inquiry-based learning is student initiated, I took my students to the pond behind the school and let them discuss with each other what they wanted to investigate and why.' (from Brenda's progress report)*. Both teachers intended to incorporate inquiry learning into the lives of their students. Brenda wanted the students to explore their own natural surroundings, while Lila wanted them to incorporate inquiry into their lives. Lila reflected on her student's ability to create research questions: *'Some students had difficulty thinking of what questions to ask. I don't know if the task assigned was difficult or that the actual writing of the question was difficult. I think that in the future I need to spend more time on technical writing and focus on the use of language.' (Lila's reflective journal)* Both teachers decided that project-based science would help them to reach their goal. We found that these teachers had similar orientations to the level 3 group. The orientations towards science teaching included project-based science, and inquiry learning: *'I have been missing out on a lot of great things that are happening in the world of inquiry-based learning. I have been using hands-on activities for many years, but I haven't allowed my students to expand on the learning. I am anxious to see how my students respond when given the opportunity to plan some of their own tracks for learning. This year I want to have them design their own projects instead of doing small hands-on activities in class.'* (Brenda's reflective journal) In the sequence of the planned classroom activities, these teachers let students decide how they wanted to answer their research questions. In this regard the teachers facilitated their plans. *'In October I placed the students in groups of four. Each group chose a habitat that was not found in our area. The groups researched their own habitats using the internet and generating questions to be answered. One group decided to seek answers in the zoo. While other groups decided to do field work. All the groups presented their findings and made a visual display for the class.' (Brenda's progress report)* Both teachers used open inquiry to facilitate their students in their projects. We found that both of these teachers were content

and inquiry-oriented using project-based learning and inquiry learning to reach their goal.

5.6. Conclusions and discussion

In this section we draw conclusions with respect to each of our two specific research questions.

RQ1: What level of inquiry do science teachers use when planning inquiry-based lessons?

We concluded that the teachers we investigated in this study operated at one of four inquiry levels when they planned their inquiry-based lessons. In particular, we found eight science teachers at the confirmation level of inquiry. They planned to start a lecture about the science concepts and then have students engage in hands-on activities concerning the concept. We also found eight science teachers at the structured inquiry level, where the teachers planned to prescribe all inquiry steps for students to follow. Six teachers planned their lessons at the level of guided inquiry. These teachers posed research questions to the students and intended to facilitate the students' own research. Only two science teachers in this study were found to plan their lessons at the level of open inquiry. They planned to encourage their students to think of research questions and to plan inquiry approaches to answer their research questions. Our study found that more teachers explored inquiry teaching at lower levels than at the higher levels. However, more research is needed with a larger sample of teachers to determine which level is more often used by teachers. Other factors such as the specific context of an inquiry and typical characteristics of the teachers will have to be further explored to determine why these teachers planned to operate at a particular inquiry level.

RQ2: How are the teachers' concerns and their orientations towards science teaching related to their levels of inquiry?

When researching the relations between the science teaching orientations and the teachers' level of inquiry, we found that although the orientations identified by Magnusson et al. (1999) were used to code the teachers' orientations in this study, we had a hard time identifying the orientation of a teacher using a single orientation from the Magnusson et al. (1999) orientations list. We found that the teachers did not hold a single orientation from the Magnusson et al. (1999) list. Rather, the majority of teachers had more than one orientation. Combinations of Magnusson et al.'s orientations (1999) were needed to determine these teachers' orientations. Previous scholars have already made references to teachers holding multiple orientations (Friedrichsen & Dana, 2005; Abell, 2007; Talanquer et al., 2010; Friedrichsen et al., 2011), arguing that orientations towards teaching are more complex than was suggested by Magnusson et al. (1999) due to factors other than the teachers' goals and purposes, such as teachers' prior work experience, professional development, and time constraints, . Magnusson et al. (1999) explained that didactic and academic rigor are teacher-centered orientations, while inquiry and project-based are considered more student-centered orientations. In our study, the teachers operating at the lower levels, that is, inquiry level 1 (confirmation inquiry) and level 2 (structured inquiry), had similar teaching orientations: didactic (or academic rigor) and activity-driven. This combination of didactic and activity-driven is indicative of orientations which are both teacher and student-centered. In earlier research, Simmons et al. (1999) noted that teachers who vacillate between student-centered and teacher-centered beliefs had difficulties planning for even if they were knowledgeable about inquiry. They reported that it takes more than just having inquiry knowledge to change the teachers' decisions to have them use inquiry-oriented teaching approaches. Teachers need to learn, rethink, and adopt different knowledge, thoughts, and practices related to inquiry-based teaching to become inquiry-minded, student-centered educators (Simmons et al., 1999, p. 948). The higher levels, level 3

(guided inquiry) and level 4 (open inquiry), were dominated by three distinct orientations: project-based, discovery, and inquiry learning. We concluded that teachers operating at the higher inquiry levels had more student-centered orientations, focusing their lessons on activities (i.e., project, inquiry, or discovery) which were mostly performed and even directed by the students. Other scholars have also noted that teachers who are inquiry-minded focus on student-centered activities in observed lessons (Rushton, Lotter, & Singer, 2011; Roehrig & Garrow, 2007).

Roehrig and Luft (2004) argued that factors other than teaching orientations may also influence the teachers' inquiry-based instructions (p. 20). These factors include the teachers' concerns about students' low ability and low motivation as well as concerns about classroom management. We therefore investigated the relations between the teachers' level of inquiry and their teaching concerns and concluded that teachers had different concerns when they engaged in different inquiry levels. Level 1 teachers were more concerned about their students' knowledge and poor test scores, whereas teachers who engaged their students in structured inquiry were also concerned about their students' poor inquiry skills. At these two lower inquiry levels, we found that the teachers were concerned about their students learning knowledge and inquiry skills, whereas at the higher two levels we saw that they were mostly concerned about the relevance of inquiry for their students' lives. In this regard we can conclude that orientations towards teaching science as well as the teachers' concerns were linked to their level of inquiry. In previous literature (Bell et al., 2005; Bianchi & Bell, 2008), it has been suggested that teachers gradually move from the lower level to a higher level of inquiry. We found that teaching at different inquiry levels may be related to teachers' concerns about teaching science. Teachers concerned about the students' lack of inquiry skills engaged their students at level 1 or 2, while teachers who wanted their students to apply their inquiry skills in other settings engaged them at level 3 or level 4 of inquiry. Moving to higher or lower inquiry levels may depend on the teachers' level of concern. Using the confirmation level

may be useful for teachers who have time constraints or want to double check whether students understood their lessons, whereas guided or open inquiry may be useful for teachers who have more time and want students to gain real life experience.

In general we can conclude that the four levels of inquiry as suggested by Bell et al. (2005) are suitable for studying inquiry-based science education. In our study we encountered all four levels of inquiry. When investigating the teachers' concerns and their orientations, we found that there were few differences between level 1 and level 2 on the one hand, and between level 3 and level 4 on the other hand. However, we found major differences between the lower levels (1 and 2) and the upper levels (3 and 4). Interestingly we found that the teachers' orientations, their classroom activities and their levels of inquiry were also related to their concerns. The concerns in level 1 were mostly at content level (lack of content knowledge), which expanded in level 2 to lack of content knowledge and lack of scientific inquiry. At level 3 and 4 we found teachers' concerns were broader, encompassing concerns about students' lack of inquiry experience in real life and real science. Teachers operating at level 3 and 4 were more concerned about students needing to transfer their learning to real life application than the teachers operating at the lower levels. Based on these findings we can argue that teachers' concerns and their orientations were important factors in determining their actions in the classroom regarding their planned classroom activities.

Based on our study we therefore suggest that the four levels of inquiry are linked to the concerns and orientations as presented in Figure 5.2. Relationships between levels of inquiry and teachers' concerns should be further investigated as should other factors in students' learning. These factors include the science curriculum, time constraints, available classroom material, and the teachers' own intention regarding inquiry teaching.

Level of inquiry	Teachers' concerns about students	Teachers' science teaching orientations
1-Confirmation	Lack of knowledge	Highly teacher oriented (such as didactic and academic rigor)
2- Structured	Lack of knowledge and skills	↕
3- Guided	Lack of knowledge and skills related to real life experience	
4- Open	Lack of application of knowledge and skills to real life science	Highly student oriented (such as inquiry and guided inquiry)

Figure 5.2. Linking the four level of inquiry model (Bell et al., 2005) with the teachers' concerns and orientations.

Teachers' concerns have been studied with pre-service teachers (de Jong & van Driel, 1999; de Jong, 2000) with a focus on their pedagogical content concerns. Little research if any is found about in-service teachers' science teaching concerns. More research is needed to find out what the concerns of in-service teachers are and how these concerns relate to their teaching. Investigating whether teacher concerns are situation or context-bound could be one focus of further research. This is important to establish whether a teacher's concern is influenced by other factors such as school policy, classroom situations, grade levels, science topics etc. Future research may also focus on the importance of the relations between a teacher's concern and a teacher's orientation towards teaching. From this study we can conclude that the teaching orientations and teachers' concerns were closely related to the inquiry levels of science teachers.

Other factors influencing teachers' levels of inquiry

We did not find clear relationships between the teachers' years of experience, their grade levels, and level of inquiry. One would expect that as teachers gain more teaching experience, they would engage in higher levels of inquiry to engage students in learning opportunities in new and challenging situations.

However, Simmons et al. (1999) found that as beginning teachers gained more experience, their beliefs became more student-centered, while their classroom actions became more teacher-centered. One would also expect that teachers who teach upper grade levels would use the higher levels of inquiry to prepare lessons aimed to engage and challenge their students to learn complex concepts. In our study, neither the teachers' years of experience nor their grade levels showed any direct and overt relationship with the teachers' level of inquiry (see Appendix B). More research with other variables is needed, however, to further explore the relationships between teaching experience and grade levels and science teachers' levels of inquiry. These other variables could include teachers' personal actions, their social interaction in class, and their personal experimentation (Simmons et al., 1999, p. 948). Perhaps future studies on teachers' beliefs and perceptions on inquiry teaching can apply longitudinal designs, where teachers' beliefs and actions are investigated over a longer period of time.

5.7. Implications

Inquiry-based instruction has been a part of science teaching for a long time (Bybee, 2004; De Boer, 2004). The goal of inquiry learning is to enhance students' ability to practice science like scientists do, using inquiry skills to develop science concepts and science process skills (Schwab, 1962). DeBoer (2004) also explained that engaging students in scientific inquiry serves many purposes including: student motivation, preparing future scientists, and developing autonomous and independent thinkers. Understanding why and how teachers construct inquiry-based lessons to engage their students in scientific inquiry could help teacher educators to prepare teachers to teach in ways that enable students to become inquiry learners. In our study we found that teachers' concerns and their orientations played an important role in their actions. PD programs that promote science as inquiry could especially benefit from our research aimed at understanding why teachers with certain concerns and orientations engage in a typical level of inquiry. The results

from this study could help teacher educators to construct PD programs where teachers with different concerns could practice using different levels of inquiry instructions and eventually develop lessons at all four levels. The MSP program is a suitable program for teachers to develop their own professional skills by preparing and conducting inquiry lessons for their own classroom that improve their teaching. Our research indicates that there is a close relationship between the teachers' concerns, their orientations and their level of inquiry. These findings may lay the basis for future studies to investigate and understand the content of these relationships.