Abstract

In this study, mathematics teachers are introduced to a new pedagogical approach to teaching statistics through inquiry-based teaching. To support the teachers, we designed a professional development trajectory anchored in peer collaboration. Four mathematics teachers from the same school collectively engaged in the development, implementation and evaluation of a new strategy to teach statistics to seventh grade pupils. By using a mixed methods approach in which we combined data from interviews, concept maps and classroom observations, we revealed how teachers changed their practical knowledge during the course of network meetings and implementation of a newly designed teaching strategy. This paper discusses opportunities for using concept maps as a source of information about teachers’ practical knowledge, especially when combined with interviews.

Keywords: Practical knowledge, teacher change, professional development, concept maps, mathematics teaching

3.1 Introduction

In many professional development efforts assessment of changes in teachers’ practical knowledge is of crucial importance. This study explores changes in teachers’ practical knowledge after they start using a new teaching approach. The study was conducted in a teacher network, consisting of four mathematics teachers who designed and implemented a new strategy for teaching descriptive statistics to seventh grade pupils. The design followed recent ideas on statistics teaching, in which students develop and conduct their own inquiry, collecting, representing, interpreting and evaluating the data themselves (Garfield & Gal, 1999). The teachers in this study were inexperienced with these strategies and collaborated in network meetings in which they discussed the objectives of the lessons, the instructional materials, the
assessment methods and lesson organization. They then individually implemented the strategy in their own classrooms and evaluated the lessons during the last meeting. Our interest in this study was to investigate which essential changes in teachers’ practical knowledge could be revealed by the use of concept maps and semi-structured interviews. More specifically, our research question is: *What changes in teachers’ practical knowledge can be unveiled, after they have designed and implemented a new teaching strategy with a network of colleagues?*

In this study, we focus on the individual differences between teachers in the network, and, more particularly, on the role concerns play in the development of practical knowledge. Further, by comparing different data sources, we investigated the use of concept maps and interviews as a method to investigate teachers’ practical knowledge.

### 3.2 Theoretical framework

#### 3.2.1 Teacher change

Many researchers have emphasized that teachers learn through reflection on their own teaching practices (Hall & Loucks, 1977; Gallagher, Goudvis & Pierson, 1988; Guskey, 2002; Clarke & Hollingsworth, 2002). Knapp (2004) and Day (1999) state that especially networks of colleagues provide powerful learning environments for teachers. Various studies (Moll, 1992; McLaughlin, 1994; Metz, 1993; Putnam & Borko, 2000; Meirink, Meijer & Verloop, 2007) have provided evidence that teacher networks provide excellent opportunities for working and learning together and result in better school results for pupils. Exchanging knowledge and experiences will trigger reflection on each other’s teaching practices and ideas, which may in turn result in an expansion of teacher knowledge and the refinement of one’s own teaching practices (Darling-Hammond, Chung Wei, Andree, Richardson & Orphanos, 2009; Borko, Mayfield, Marion, Flexer & Cumbo, 1997).

Day (1999) suggested that a network is effective for teachers if it sets challenging and concrete goals, if it enables interaction with colleagues, if there is continuity in the meetings (i.e. revision of what has been learned, or being confronted with new ideas by colleagues) and if attention is paid to problems in teachers’ individual teaching practices. McDonald and Klein (2003) analysed a variety of teacher networks and reported on their role in teacher change. They distinguished a number of functions of networks, which also play an important role in this study, such as developing teachers’ content knowledge and pedagogical content knowledge, enhancing
teaching, implementing and evaluating new practices and reforms and providing access to expertise.

### 3.2.2 Teachers' practical knowledge

Fenstermacher (1994) referred to 'practical knowledge' as the knowledge teachers themselves generate as a result of reflections on their experiences. As it is constructed by teachers in the context of their work, practical knowledge integrates experiential knowledge, formal knowledge and personal beliefs (Van Driel, Beijaard & Verloop, 2001). Teachers’ practical knowledge may be conscious or unconscious (Meijer, Verloop & Beijaard, 1999). Furthermore, it includes both a content-related component (Shulman, 1986a) and a personal component.

According to the content-related component of teachers’ practical knowledge, which is related to knowledge and skills, Shulman (1986a) developed categories. Other studies (Grossman, 1989; Van Driel, Verloop & De Vos, 1998; Meijer, 1999) have adapted Shulman’s categories. Our study relies on one of these (Meijer, 1999, p. 49, 61), adapted for statistics education:

1. Subject matter knowledge: knowledge of statistics (see also Sowder, 2007);
2. Student knowledge: statistical knowledge of the students, their motivation and their environment;
3. Knowledge of student learning and understanding: knowledge of students’ learning and understanding of statistics;
4. Knowledge of purposes: knowledge of goals for statistics teaching and their importance;
5. Curriculum knowledge: knowledge of texts and materials for statistics education and knowledge of the content of the statistics curriculum;

These categories are more fine-grained than Shulman’s categories, as the above-mentioned categories 3, 4, 5 and 6 can be considered pedagogical content knowledge (PCK, Shulman, 1986b). Category 2 is similar to what others have called ‘knowledge of context’ (Magnusson, Krajcik & Borko, 1999).

The personal component of teacher knowledge is the product of a teachers' personality, his background and personal experiences. This component includes teachers' values, (efficacy-)

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beliefs, attitudes, and ideologies (Meijer, Verloop & Beijaard, 2001; Clarke & Hollingsworth, 2002; Bandura, 1986). According to Brown and McIntyre (1993) this component of practical knowledge guides a teacher’s judgments about appropriate actions in concrete and specific situations. At the same time this personal component of teachers’ knowledge may be the source of concerns about the usefulness of new approaches to teaching (Fullan, 1993; Fullan & Stiegelbauer, 1991). Recognition of these concerns in professional development trajectories is important, since they may indicate teacher’s readiness to continue using and refining newly adopted teaching practices. Van den Berg (2002) makes a distinction between three types of concerns that may pop up when teachers engage in new forms of teaching: (1) self-concerns, related to the person himself; (2) task-concerns, related to the worries, needs and questions about the processes and demands of new teaching practices; (3) impact-concerns, related to attention to colleagues and pupils. In our study, we define teachers’ practical knowledge as ‘the knowledge, skills and beliefs teachers use to practice their profession’. Thus, we use knowledge, skills and beliefs interchangeably.

3.2.3 Concept mapping

Concept maps are graphic representations of knowledge, comprising concepts and the relationships between them (Novak & Gowin, 1984). Rice, Ryan and Samson (1998) and McClure, Sonak and Suen (1999) have reported on the reliability and validity of concept map assessments. Rice et al. (1998, p. 1106) mention that the use of concept maps is not limited to any particular group of learners and that concept mapping can be easily and quickly taught to learners. They used concept maps to assess students’ achievement in relation to knowledge of terms and concepts in life science, and concluded that concept maps may be very useful as a single-format assessment technique with multiple scoring approaches. McClure et al. (1999) gave students a list of terms and asked them to produce a concept map. They report that if procedures for creating maps are not well specified, the variation in students’ maps may make interpretation difficult, which reduces the validity of the conclusions. McClure et al. (1999, p. 477) mention that some factors decrease the reliability of concept maps: (1) variations in subjects’ concept mapping proficiency, (2) variations in the content knowledge of those evaluating the concept maps, and (3) the consistency with which the concept maps are evaluated. They conclude that the concept mapping task should not be so complex as to distract the
mappers, nor so simple as to sacrifice representational clarity. They found that the ‘relational scoring method’ is the most reliable method when augmented with a master map, constructed by the course instructor (see also McClure & Bell, 1990).

Several researchers recommend combining concept maps with other data sources (Rice et al., 1998; McClure et al., 1999; Van Zele et al., 2004), such as interviews and questionnaires (e.g. Meijer, 1999) or video and audio recordings (e.g. Ummels, Kamp, De Kroon and Boersma, 2013). Meijer’s (1999) conclusion was that concept maps are useful to measure teachers’ practical knowledge if combined with interviews in which the map is explained by the teachers.

In our study we applied a relational scoring method by using teachers’ first concept maps as a reference. Concept maps were mainly analysed qualitatively, to provide a non-directive distillation of the practical knowledge of teachers. We might detect changes in both teachers’ personal- and content-related practical knowledge and we might be able to identify possible teacher concerns.

3.3 Method

3.3.1 Participants
This study comprises four mathematics teachers from the same school, a large comprehensive school in a small town in The Netherlands. The four teachers voluntarily signed up for participation in this study.

A questionnaire, with a total of 17 closed-format questions, was used to collect information about the teachers’ background variables. Table 3.1 contains relevant information about the participating teachers. Teachers’ names have been changed for reasons of privacy. Table 3.1 shows that the teachers had a great deal of teaching experience (ranging from 6 to 23 years). The teachers all used traditional methods, relying on textbooks and lessons in which pupils mainly worked on exercises, and the table shows that teachers had little experience with the use of statistical research assignments and little or no experience with inquiry-based teaching or project work. The teachers had little statistical knowledge, but to their own opinion enough for teaching statistics in de lower grades of secondary school.
Table 3.1: General information about the participants in the study during the school year 2006-2007

<table>
<thead>
<tr>
<th>Name of teacher</th>
<th>Sex</th>
<th>Age</th>
<th>Number of years of experience in education</th>
<th>Number of years of teaching in the first stage of secondary school</th>
<th>Expertise in statistics</th>
<th>Experience with creating and supervising statistical research projects</th>
<th>Attended network meetings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annet</td>
<td>Female</td>
<td>48</td>
<td>10</td>
<td>3</td>
<td>‘Knowledge has quite subsided’</td>
<td>‘Not much, I assisted during a statistics project in the 9th grade of senior general secondary education’</td>
<td>1-7 (all)</td>
</tr>
<tr>
<td>Bart</td>
<td>Male</td>
<td>47</td>
<td>18</td>
<td>18</td>
<td>‘Too little; enough for grades 7–10’</td>
<td>‘I did a small statistics project in the 9th grade of junior general secondary education’</td>
<td>1-7 (all)</td>
</tr>
<tr>
<td>Christine</td>
<td>Female</td>
<td>47</td>
<td>23</td>
<td>23</td>
<td>‘In teacher training, long ago (1987)’</td>
<td>‘None’</td>
<td>1-4 &amp; 7</td>
</tr>
<tr>
<td>David</td>
<td>Male</td>
<td>56</td>
<td>6</td>
<td>6</td>
<td>‘During study and professionally’</td>
<td>‘During my study as a student assistant. But also as a social science researcher (app. 10 years)’</td>
<td>1 &amp; 4-7</td>
</tr>
</tbody>
</table>
3.3.2 Network meetings
The teacher network in this study met the conditions mentioned in section 3.2.1. The network meetings aimed at setting goals, sharing experiences, and jointly developing and evaluating the teaching design. To achieve the aims of the network meetings, we set up a series of planned events (table 3.2). Each network meeting lasted 50 to 90 minutes. After network meeting 6 teachers implemented the design in their classrooms. During the evaluative network meeting 7 they had the opportunity to exchange experiences and to reflect on their own experiences.

The facilitator, also researcher, organized and moderated the network meetings and provided the teachers with information, for example, in the form of relevant literature. The facilitator was present at all meetings. Her role was to stimulate discussions, but she did not interfere with suggestions on designing and implementation issues.

<table>
<thead>
<tr>
<th>Network meeting</th>
<th>Planned events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-6 First network meeting on 4 April 2006. Sixth meeting on 31 October 2006</td>
<td>1. Development of a teaching design, including objectives, student assignments, organisation of group work, knowledge test and pedagogies. 2. Introduction to inquiry-based teaching and examples of statistics teaching (e.g. software packages) 3. Renewed acquaintance with statistics by, for example, reading literature. 4. Organisation of the implementation of the teaching design. 5. Creating commitment to the subject and to the group by making agreements on carrying out plans and tasks.</td>
</tr>
<tr>
<td>7 Evaluative network meeting on 18 December 2006</td>
<td>1. Reflection on the joint development of the teaching design. 2. Reflection on classroom experiences. 3. Indicating points for improvement in the teaching design and its implementation.</td>
</tr>
</tbody>
</table>
3.3.3 Research design and data sources

The research instruments included concept maps, semi-structured interviews and lesson observations. Lesson observations were used to check out interpretations based on the other data sources. By triangulating our findings from different research instruments we were able to check the validity of our conclusions about teachers’ practical knowledge (see also Meijer, Verloop & Beijaard, 2002; Denzin, 1970).

3.3.3.1 Concept maps

A pre-concept map (CM[0]) was drawn up during the first network meeting and a post-concept map (CM[1]) was drawn up during the seventh meeting. Teachers received written instructions on how to create a concept map and were given an example with a different central concept (i.e. ‘what do you associate with camping?’). In the concept mapping assignment, teachers were asked to generate concepts related to the central theme (‘learning and teaching statistical research skills’) and to organize these concepts into a map. They were also asked to number their core concepts from 1 till 5, also if their maps consisted more than five concepts. In discussion sessions directly after the drawing up of the concept maps, the researcher asked the teachers to clarify the concepts and the connections between them. These discussion sessions lasted about 30 to 40 minutes and were recorded and transcribed verbatim.

3.3.3.2 Semi-structured interviews

Individual semi-structured interviews (Int[0] and Int[1]) were held directly after the concept map discussions. The interviews were also recorded and transcribed verbatim. Both interviews contained the same, ten questions. These questions sometimes overlapped with the themes of the concept map discussions, and the interview thus supplemented these discussions. The teachers were asked how they thought pupils learn statistical research skills and how these skills should be taught. In addition, questions were asked with regard to the goals of conducting statistical research and the teacher’s role in research conducted by pupils, and whether and in which phase of research statistical subject matter content plays a role. The semi-structured interview took about 15 to 20 minutes per teacher.

3.3.3.3 Lesson observations

A total of nine lessons were planned to conduct the teaching strategy. All of the fifty minutes lessons of all four teachers were recorded with a video camera, focusing on the teachers’
activities. The lessons were used to check if their teaching practice aligned with their practical knowledge that appears from concept maps and interviews.

### 3.3.4 Data analysis

The total number of concepts in the pre- and in the post concept map were counted. Discussions about concept maps and the semi-structured interviews yielded a large number of statements from individual teachers. For each teacher, we used these statements to examine which concepts in the first and the second concept map matched, while the differences were also identified. In this way, we got a list of recurring concepts as well as those arising for the first time. Meijer’s (1999) classification (see section 3.2.2) was used to categorize concepts, originating from concept maps, discussions of concept maps and interviews. Using Meyer’s classification we determined the emphasis of the concept maps as teacher-oriented, pupil-oriented, subject matter oriented, goal-oriented, etc. Subsequently, we divided teachers’ statements into refining themes, within Meijer’s knowledge categories, which we thought indicated the core of their practical knowledge.

From lesson observations we inferred the way the teachers implemented the teaching strategy and checked whether the teacher’s actions reflected their statements during the concept map discussions and interviews.

Classification of statements and concepts from maps in Meyer’s categories and themes were discussed afterwards by the researcher and co-authors until consensus was reached. After analysing all the data on the teachers’ practical knowledge, a set of three categories and descriptions of teachers’ practical knowledge could be distilled, and in total nine refining themes.

Finally, we determined teachers’ initial and final practical knowledge and related this knowledge to Meijer’s categories and to the observed lessons. Statements from teachers in each of the three categories were then analysed for possible concerns. In determining differences between teachers’ initial and final practical knowledge, we might be able to identify teacher change.

### 3.4 Results

In this section we present the teachers’ initial and final practical knowledge as discerned from transcripts of the concept map discussions and interviews. We categorized fragments according to Meijer’s (1999) categories of practical knowledge and subdivided these into themes. Appendix 3.1 contains an example of a pre- and a post concept map.
3.4.1 Annet

The number of terms increased from 10 in the initial map to 18 in the second map. In her first concept map (CM[0]) Annet focused on the research procedure ‘as she had learned herself’: ‘choose a topic – state hypothesis – state questions and sub-questions – administer questionnaire, conduct field research – collect data, order data’. In her second concept map (CM[1]), Annet shifted towards a sequencing of the inquiry process for her pupils: ‘design – conduct (questionnaire, search for information) – answer question – present research’. In her pedagogical goals she shifted from the teacher’s perspective (‘theoretical background, planning and supervising’) to the pupil’s perspective (‘collaboration, group composition, division of tasks, choice of topic’). Furthermore, the subject matter became more detailed (‘statistical concepts: mean, mode, median, frequency’). During the intervention her concept map dramatically changed from a goal-oriented to a student-oriented perspective.

Annet’s initial and final practical knowledge fits into Meijer’s categories of ‘Knowledge of purposes’, with refining themes Inquiry process and Statistical literacy; ‘Knowledge of student learning and understanding’, with refining theme Pupils’ pre-knowledge; ‘Knowledge of instructional strategies’, with refining themes Autonomy of pupils and Group work. Initially she emphasized the importance of learning about inquiry, connecting this to pupils’ daily life and fostering autonomy, as shown in her statements ‘I believe that they can master it by experiencing the entire process’ (CM[0]), ‘I believe that it’s important to take into account what they already know in order to actually teach them something’ (CM[0]), and ‘So that’s very much my role – creating the conditions. Directing them as little as possible, while still offering them sufficient guidance’ (CM[0]).

Annet’s second map focused on her experiences during the design and teaching process. She mentioned the need for statistical literacy: ‘That they learn how all these numbers end up in the book’, (Int[1]), pupil autonomy: ‘It’s their project. And if they see it this way as well, they will put in a good effort’ CM[1], group work: ‘And the collaboration itself has really surprised me as there are children who can’t work in groups’ (CM[1]), and a good introductory assignment for pupils: ‘Now I would provide my pupils with an entirely different introduction assignment. But I would still let them try themselves since the outcome of that is invaluable’ (Int[1]). With this, we may conclude that Annet’s topics of concern are Statistical literacy, Pupil autonomy and Group work. The lesson observations showed Annet’s flexibility: she deviated from the agreements made in the network when the classroom situation required this. As she insisted on the pupils’ ownership of the project, she guided
them towards a good research question. Although she doubted the effectiveness of the introductory assignment because pupils did not sufficiently know what statistical research was, she motivated them to carry out their own research. Furthermore, she seemed to be concerned about the way pupils worked in groups and her own role in guiding these groups.

3.4.2 Bart

The number of terms in Bart’s concept maps decreased from 22 to 18. In CM[0] Bart focused on the instruction of statistical concepts: ‘mean – frequency – sample – accuracy – box plot – circle diagram’. Bart also mentioned ‘gaining insight’ and ‘pedagogy’ as his main emphases. His reflections on group work focused on products: ‘poster – power point presentation’. CM[1] showed a shift towards the way to create the end products: ‘presentation – poster materials – power point – review – survey – internet – sample’. His remarks on group work focused on processes: ‘division of tasks – collaboration’. In CM[1] the terms ‘gaining insight’ and ‘pedagogy’ disappeared. He explained: ‘I believe the pedagogical part is rather difficult. I never really managed to get started on it (…). Well, that’s because I was mainly concerned with the organization’, and: ‘Yes, of course, gaining insight is also very important. I didn’t mention it and that’s partly because I did not have the idea that they gained any insights’.

Bart’s initial practical knowledge fits into Meijer’s categories of ‘Knowledge of purposes’, with refining themes Statistical literacy and Concept learning; ‘Knowledge of instructional strategies’, with refining themes Pedagogical strategies and Group work. He emphasized the importance of ‘gaining insight’ and ‘subject matter’, stating for example ‘While performing research assignments, pupils learn less about the subject’s content. (…). The pupils are perfectly able to work together, but they don’t really know what to do’ (Int[0]), and ‘pedagogy in the classroom’, mentioning ‘Discussing the results, of course. Showing them the possibilities. Making sure they deal with it in a certain manner by offering a different approach’ (Int[0]).

Bart raised concerns with respect to ‘group work’ and ‘pedagogy in the classroom’: ‘I see the purpose in doing it as it stimulates all sorts of skills. (…) I opt for it myself, but then I kept on thinking: ‘I’m not sure, it takes up too much time’ (CM[0]). These concerns were grounded in previous teaching experiences. After the intervention, Bart said that the trajectory was quite demanding for him. After the implementation he repeated his concerns, for example about group work ‘The main problem with the instructional strategies is that it takes up so much time and effort. I believe there is a better way’ (Int[1]), which were apparently confirmed by his experiences during the lessons.
3.4.3 Christine

The number of terms in both concept maps were almost the same: 16 and 15. Both concept maps focused on applying statistical concepts and statistical research skills. Her CM[0] showed no clear focus, with the various terms including: ‘pupils’ reading ability – searching for information – classify – interpret – daily life – attractive topics’. Her CM[1] was more coherent, with terms such as: ‘choose topic – information – knowing measures of centre – interpret results – describe connections’.

Christine’s practical knowledge fits into Meijer’s categories of ‘Knowledge of purposes’, with refining themes Statistical literacy and Concept learning; ‘Knowledge of student learning and understanding’, with refining themes Pupils’ pre-knowledge and Pedagogical strategies; ‘Knowledge of instructional strategies’, with refining themes Guidance of pupils and Group work. She emphasized the importance of ‘the transfer of skills to other situations’ (CM[0]). Initially Christine’s statements were rather general, such as noting the importance of ‘pupils’ reading ability’ (CM[0]) or ‘guiding pupils by asking questions’ (Int[0]). Her final practical knowledge was less general and more related to statistics, as shown by her statement ‘Yes, but it was hard to give pupils the direction in their search for mathematical relations, because we didn’t introduce it’ (CM[1]). Christine expressed great confidence in her pupils: ‘I thought my groups managed to come up with some decent work. It was accessible and clear, and pupils could focus on answering their own research question’ (CM[1]). During lessons, Christine showed enthusiasm and she gave the pupils various opportunities, for example, giving them permission to collect data outside the classroom. After the intervention, Christine was more confident in guiding groups. She stated ‘We had to give the pupils some direction in forming their research question. Pupils can work from there’ (CM[1]), and ‘In selecting the groups, I found it striking that both Annet and I actually managed to come up with good results. Pupils in those groups worked really well, while problems occurred in groups that pupils had formed themselves’ (CM[1]). Christine used her initial concerns about group work to improve her educational output.

3.4.4 David

In David’s concept maps, the number of terms decreased from 42 to 19. However, in his first concept map he very schematically represented questions and their answers in different boxes. The focus of the first concept map was rather analytical with respect to research phases: on the right side he described the phases of scientific research as he saw them, on the left side of the concept map he described conditions, the role of the teacher and the evaluation
of the research. The terms were about educational quality, statistics and methodology. Since
the research process was important to David, as shown by his statement ‘Given my own
research experience I always deal with things in a chronological manner rather than within a
conceptual frame’ (CM[0]), the emphasis was on pedagogical goals. In his second concept
map, David shifted towards a sequencing of the inquiry process that was more suitable and
applicable to his pupils. On the left side, he described the research phases, ‘orientation –
which was an abridged version of the research phases from the first concept map. On the
right side of the concept map, he described: ‘pilot conditions – teacher – vision – curriculum’.
These terms aimed at the implementation of the teaching strategy and on the preconditions
for conducting inquiry.

David’s practical knowledge fits into Meijer’s categories of ‘Knowledge of purposes’, with
refining themes Inquiry process, Statistical literacy and Concept learning; ‘Knowledge of
student learning and understanding’, with refining themes Pupils’ pre-knowledge and Pupils’
learning; ‘Knowledge of instructional strategies’, with refining themes Guidance of pupils
and Group work. In his initial practical knowledge he emphasized the importance of a
chronological inquiry process and statistical literacy, he stated for example ‘For me this is a
central goal. The reason you work with mathematics is to systematically analyze something’,
(CM[0]). In his final practical knowledge he revealed his progressive ideas and linked these
to experiences during lessons. However, he never mentioned ‘the pupils’, except for pupils’
pre-knowledge. He argued beforehand that ‘You look at a competence such as analytical
ability, to name one. It’s just too abstract for pupils at this level, (Int[0])’, and afterwards
‘Now I saw pupils struggling with problems(self-selected topics) I interpreted as: ‘Either too
ambitious or too simple’ (CM[1]).

The interviews reflect many concerns, particularly after the intervention. He seems rather
concerned about the outcomes of the lessons. For instance, initially he was positive about his
role in the group work (‘I’ll have the role of coach’, Int[0]), but afterwards he saw himself
only as a provider of information. He argued for a pilot to identify the gaps in the teaching
strategy (‘A pilot is a very important precondition’ CM[1]), which means that he had serious
doubts about positive outcomes.

David’s idea about pupil learning was characteristic of his approach. He mentioned that
‘pupils need a longer period to get used to new ideas’ (Int[1]). Perhaps this reveals David’s
way of learning and dealing with changes. Lesson observations showed that the atmosphere
in the classroom was a little chaotic and that David did not really take the lead. He
mentioned: ‘The size of the groups depends on the guidance. I believe there are too many groups to help all at once’ (CM[1]), which may explain the situation in the classroom. His statement: ‘You are the oracle or walking encyclopaedia. You provide the knowledge. You will give them an explanation so that they know what to do next. When they’re busy with the exercise, the teacher is a guide for his/her pupils’ (Int[1]), seems to describe his ideal situation.

3.5 Conclusions and discussion
The results show that our network strategy was successful to some extent. Teachers’ jointly working on a teaching design and its subsequent implementation enabled teachers to reflect on their knowledge and skills and extend their practical knowledge.

The results also show the diverse nature of the teachers’ development and the changes in their practical knowledge. The concept maps helped to bring structure into changed aspects of teachers’ practical knowledge. Two teachers continuously set new goals to improve their lessons. The other two expressed concerns regarding new teaching strategies. Annet and Christine focused on conditions that improved learning results and the learning process of their pupils (impact concerns), while Bart and David were preoccupied with the task of delivering the textbook content. They had doubts from the beginning about the efficiency of the new teaching approach, with David advocating a pilot study and Bart continuously mentioning the lack of time and loss of control in the classroom. The teachers’ readiness to implement inquiry-based teaching seems influenced by their practical knowledge, for example, about ‘group work’ or ‘statistical content’. Annet and Christine emphasized that pupils should learn research and collaboration skills, which were, according to them, just as important as learning the statistical concepts. Bart and David, on the other hand, were primarily concerned to teach statistical knowledge, possibly conditioned by the textbook (task concerns).

Changing their teaching practice raised what Fuller (1969) called ‘late concerns’ among the teachers. These concerns can take either a positive or negative form. An example of a positive concern is Christine’s statement: ‘We’ll pay more attention to preconditions’. These concerns are seen as challenges in a continuous learning process. Negative concerns, on the other hand, hinder teachers from further improving their practice. It seems that these negative teacher concerns are linked to an approach in which ‘subject matter content’ is predominant. Our findings also demonstrate that teachers’ efficacy beliefs are important in their further professional development and educational change. According to Timperley, Wilson, Barrar
and Fung (2008), for substantive learning, such as that involved in mathematical problem solving, pupils need extended time for learning and changing, which might also be true for teachers. It may take one to two years for teachers to understand how existing beliefs and practices are different from those needed in educational reforms, to build the required pedagogical content knowledge, and to change their practice. It seems that, if teachers don’t worry anymore about whether or not they are capable to handle new situations, they are able to focus on achieving learning outcomes for pupils or on making a teaching design more efficient.

Although networks are considered as effective in influencing teachers’ efficacy beliefs (McDonald & Klein, 2003), we were not successful in realizing this with all teachers participating in our network. It is our impression that Bart and David needed more time to adopt novel teaching strategies. According to Timperley et al. (2008), time is not a sufficient condition for change: teachers also need to have their current practice challenged and to be supported as they make changes. We are also aware that we should further improve our professional development strategies. However, our network was an environment characterized by both trust and challenge. This is important as change involves both teachers’ emotions and teachers’ knowledge and skills (Timperley, et al., 2008). It should be noted here that both Bart and David wanted to continue the inquiry-based projects in the following school year, suggesting that their experiences were not so negative that they wished to stop the teaching experiment altogether. However, it seems likely that both teachers need support during the implementation of the teaching design. We should be aware that learning content through engagement in meaningful activities, supported by a rationale for participation that is based on identified student needs, has a greater impact on student outcomes than the circumstances that lead teachers to sign up (Timperly, et al., 2008). Our study supports this view, as due to commitment to the group, Bart and David were willing to continue in the professional development trajectory.

This study reveals that use of concept maps yields useful information about teacher change in a specific subject if used in combination with interviews and lesson observations. However, the meaning of an increase or decrease of the number of concepts is not immediately obvious. An increase of the number of concepts may indicate a refinement of teachers’ practical knowledge. A decrease of the number of concepts may indicate a fragmented view on the central theme in the initial concept map. In general, it is much more difficult to build a good,
accurate concept map about a topic with a small number of concepts (e.g., four or five) than with fifteen to twenty concepts (see Novak & Cañas, 2006). An explanation of the emergence of new or more concepts needs to be distilled from additional data sources, like discussions of concept maps and interviews.

Concept maps rendered an overview of the practical knowledge teachers activated when preparing a series of lessons. The information value of concept maps is limited. However, the overview serves as an excellent agenda for a subsequent discussion on the concepts selected by the teacher – and those not selected – and connections between concepts. The combination of concept maps and discussion gives insights into teachers’ practical knowledge. Additionally, interviews gave the possibility to question the teachers more in-depth and lesson observations revealed teachers’ action in the classroom, which served as addition to the information from concept maps and interviews, providing more details on their practical knowledge.
References


Appendix 3.1: Pre- and Post-Concept maps of Annet

3.1A: Pre-Concept map of Annet, 24 April 2006
In the pre-concept map of Annet, the most important concepts according to Annet are marked from 1 to 5.
3.1B: Post-Concept map of Annet, 18 December 2006

In the post-concept map of Annet, the most important concepts according to Annet are printed in bold.