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The impact of peer collaboration on teachers' practical knowledge

Martha Witterholt[a]*, Martin Goedhart[b] and Cor Suhre[a]

[a]*Faculty of Behavioural and Social Sciences, Teacher Education, University of Groningen, Groningen, The Netherlands;* [b]*Faculty of Mathematics and Natural Sciences, Didactics and Curriculum Development – FMNS Research, University of Groningen, Groningen, The Netherlands*

Due to changes in Dutch mathematics education, teachers are expected to use new teaching methods such as enquiry-based teaching. In this study, we investigate how teachers design, implement and evaluate new methods for statistics teaching for 7th-graders during a professional development trajectory based on peer collaboration. We monitored teachers' development in a network of four mathematics teachers from the same school. By using a mixed-methods approach in which we combined data from interviews, concept maps and classroom observations, we describe changes in teachers' practical knowledge. We found how the nature of these changes highly depends on teachers' personal concerns that emerge during the trajectory. Some teachers considered their concerns as challenges stimulating their learning, while other teachers experienced their concerns as a reason to fall back to previous teaching methods. Based on our results, we give some recommendations for organising teacher networks.

Keywords: practical knowledge; teacher change; professional development; concept maps; mathematics teaching

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 from the same school 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 enquiry, collecting, representing, interpreting and evaluating the data themselves (Garfield and Gal 1999). In this study, we focus on the viability of assessing changes in teachers' practical knowledge by means of concept maps and semi-structured interviews. Our special interest lies in determining the usefulness of this data collection method to uncover the nature and causes of changes in teachers' practical knowledge.

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?*

*Corresponding author. Email: m.g.witterholt@rug.nl

2. Theoretical framework

2.1. Teacher change

Many researchers have emphasised that teachers learn through reflection on their own teaching practices (Clarke and Hollingsworth 2002; Gallagher, Goudvis, and Pearson 1988; Guskey 2002; Hall and Loucks 1977). Knapp (2004) and Day (1999) state that especially networks of colleagues provide powerful learning environments for teachers. Various studies (McLaughlin 1994; Meirink, Meijer, and Verloop 2007; Metz 1993; Moll 1992; Putnam and Borko 2000) 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 (Borko et al. 1997; Darling-Hammond et al. 2009).

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. summarising the issues that have been discussed and making explicit new ideas raised by the teachers) and if attention is paid to problems in teachers' individual teaching practices. Darling-Hammond (1998) and Taylor (2004) also refer to teacher collaboration in order to improve their practice.

McDonald and Klein (2003) analysed a variety of teacher networks. Based on their findings, they hypothesise that networks should equally focus on developing teachers' content knowledge and pedagogical content knowledge. Networks should be used to discuss both the teachers' individual practices and the more general theoretical perspectives.

The above-mentioned functions of networks play an important role in this study, aiming at developing teachers' practical knowledge, enhancing teachers' efficacy, implementing and evaluating new practices, and providing access to expertise.

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, and Verloop 2001). Teachers' practical knowledge may be conscious or unconscious (Meijer, Verloop, and Beijaard 1999). Furthermore, it includes both a content-related component (Shulman 1986a) and a personal component. In our study, we define teachers'practical knowledge as 'the knowledge, skills and beliefs teachers use to practice their profession'.

According to the content-related component of teachers' practical knowledge, which is related to knowledge and skills, Shulman (1986a) developed categories. Other authors (Grossman 1989; Meijer 1999; van Driel, Verloop, and de Vos 1998) have adapted Shulman's categories. Our study relies on one of these (Meijer 1999). We distinguish following categories of teachers' practical knowledge specified for statistics education:

(1) Knowledge of subject matter: teachers' knowledge of statistics (see also Sowder 2007);

(2) knowledge of students: knowledge of teachers' own students' mathematical abilities, 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) knowledge of curriculum: knowledge of texts and materials for statistics education and knowledge of the content of the statistics curriculum;
(6) knowledge of instructional strategies: knowledge of design, preparation and structure of lessons in statistics.

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, and Borko 1999).

The personal component of teacher knowledge includes teacher's values, (efficacy-) beliefs, attitudes and ideologies (Bandura 1986; Clarke and Hollingsworth 2002; Meijer, Verloop, and Beijaard 2001). At the same time, this personal component of teacher knowledge may be the source of concerns about the usefulness of new approaches to teaching (Fullan 1993; Fullan and 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.

2.3. Concept mapping

Concept maps are graphic representations of knowledge, comprising concepts and the relationships between them (Novak and Gowin 1984). One way to use concept maps is to have people represent the knowledge they activate during the performance of different tasks. Differences in the application of concept maps concern the kind of relations between concepts that are depicted and whether the concepts are prestructured by the researcher (Van Gog et al. 2009), the number of concepts used and in the terminology used to refer to a certain concept (de Jong and Ferguson-Hessler 1986; Nievelstein et al. 2008; Stoyanov and Kirschner 2004; Trochim 1989; Wopereis et al. 2005).

In this study, we use concept maps to represent the nature of the knowledge teachers consider relevant at the beginning of their cooperative initiative to design and implement enquiry-based teaching and nine weeks after the start. Comparisons between maps of the same teacher at different moments may give valuable insights into the teachers' knowledge (Schvaneveldt et al. 1985). Several researchers recommend combining concept maps with other data sources (McClure, Sonak, and Suen 1999; Meijer 1999; Rice, Ryan, and Samson 1998; Ummels et al. 2013; Van Zele, Lenaerts, and Wieme 2004). The concept maps in this study will be supplemented with interviews so as to allow teachers to clarify the relationships between concepts and to investigate the focus of their thoughts concerning changing their education.

Rice, Ryan, and Samson (1998) and McClure, Sonak, and Suen (1999) have reported on the reliability and validity of concept map assessments. Rice, Ryan, and Samson (1998, 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, Sonak, and Suen (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, Sonak, and Suen (1999, 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) lack of 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 course instructor or researcher (see also McClure and Bell 1990).

3. Method

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. Relevant results are presented in Table 1. Teachers' names have been changed for reasons of privacy. Table 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 enquiry-based teaching or project work. The teachers had little statistical knowledge, but to their own opinion enough for teaching statistics in the lower grades of secondary school.

3.2. Network meetings

The teacher network in this study met the conditions mentioned in Section 2. 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 2). Each network meeting lasted 50–90 min. 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, organised and moderated the network meetings and provided the teachers with information, for example, in the form of relevant

Table 1. General information about the participants in the study during the school year 2006–2007.

Name of teacher	Sex	Age	Number of years of experience in education	Number of years of experience teaching in the first stage of secondary school	Expertise in statistics	Experience with creating and supervising statistical research projects	Attended network meetings
Annet	Female	48	10	3	'Knowledge has quite subsided'	'Not much, I assisted during a statistics project in the 9th grade of senior general secondary education'	1–7 (all)
Bart	Male	47	18	18	'Too little; enough for grades 7–10'	'I did a small statistics project in the 9th grade of junior general secondary education'	1–7 (all)
Christine	Female	47	23	23	'In teacher training, long ago (1987)'	'None'	1–4 & 7
David	Male	56	6	6	'During study and professionally'	'During my study as a student assistant. But also as a social science researcher (app. 10 years)'	1 & 4–7

Table 2. Overview of planned events during the network meetings.

Network meeting	Planned events
1–6	1. Development of a teaching design, including objectives, student assignments, organisation of group work, knowledge test and pedagogies
First network meeting on 4 April 2006. Sixth meeting on 31 October 2006	2. Introduction to enquiry-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
7	1. Reflection on the joint development of the teaching design
Evaluative network meeting on 18 December 2006	2. Reflection on classroom experiences 3. Indicating points for improvement in the teaching design and its implementation

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.

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 Denzin 1970; Meijer, Verloop, and Beijaard 2002).

3.3.1. Concept maps

In our study, we applied a relational scoring method by using teachers' first concept maps as a reference (see also Section 2.3). 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 organise 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 30–40 min and were recorded and transcribed verbatim.

3.3.2. Semi-structured interviews

Individual semi-structured interviews (Int[0] and Int[1]) were held directly after the concept map discussions. Interview questions were about teachers' ideas about teaching and learning (statistical) research skills, goals of (statistical) research assignments, and their former experiences in guiding and assessing (statistical) research assignments. The interviews were also recorded and transcribed verbatim. Both interviews contained the same 10 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 15–20 min per teacher.

3.3.3. Lesson observations

A total of nine lessons were planned to conduct the teaching strategy. All of the 50-minute 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.

3.4. Data analysis

Concept maps were mainly analysed qualitatively, by comparing the pre- and post-concept map of the same teacher. The total number of concepts in the pre- and in the post-concept maps was 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 2.2) was used to categorise 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.

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 categorised fragments according to Meijer's (1999) categories of practical knowledge and subdivided these into themes. Appendix 1 contains an example of a pre- and a post-concept map.

4.1. Annet

In Annet's concept maps, 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 enquiry 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'). After the intervention, her concept map has changed significantly from a task-oriented to a student-oriented perspective. Annet's pre-concept map focuses primarily on the tasks she needs to conduct in order to stimulate all students to work. Annet's post-concept map shows that she now focuses on how to guide students' learning while structuring tasks and on refining her teaching.

Annet's initial and final practical knowledge fits into Meijer's categories of 'Knowledge of purposes', with refining themes Enquiry 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 emphasised the importance of learning about enquiry, 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.

4.2. Bart

The number of terms in Bart's concept maps decreased from 22 to 18. In CM[0], Bart focused on 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 organisation', 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' CM[1]).

Bart's initial practical knowledge fits into Meijer's categories 'Knowledge of purposes', with refining themes Statistical literacy and Concept learning; 'Knowledge of instructional strategies', with refining themes Pedagogical strategies and Group work. He emphasised 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 Pedagogical strategies: '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 so much time and effort. I believe there is a better way' (Int[1]), which were apparently confirmed by his experiences during the lessons.

4.3. Christine

The number of terms in Christine's 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' preknowledge and Pedagogical strategies; 'Knowledge of instructional strategies', with refining themes Guidance of pupils and Group work. She emphasised 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.

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 enquiry process that was more suitable and applicable to his pupils. On the left side, he described the research phases 'orientation – problem exploration – problem – goals – research design – implementation – evaluation', 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 enquiry.

David's practical knowledge fits into Meijer's categories of 'Knowledge of purposes', with refining themes Enquiry 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 emphasised the importance of a chronological enquiry process and statistical literacy. He stated, for example, 'For me this is a central goal. The reason you work with mathematics is to systematically analyse 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.

5. Conclusions and discussion

The aim of this paper was to unveil changes in teachers' practical knowledge after they have designed and implemented a new teaching strategy with a network of colleagues. The network approach was applied, as this provides a powerful learning environment for teachers in which discussion and reflection creates continuous opportunities for changes in teachers' practical knowledge. The network in which teachers jointly worked on a teaching design in the domain of statistics and subsequently implemented it, enabled them to reflect on their knowledge and skills and extend their practical knowledge. This finding is in line with others exploring this approach (see for example Day1999; Guskey 2002; Knapp 2004; McDonald and Klein 2003). Little (1990) calls this type of collaboration 'joint work', as the emphasis is on shared responsibility for teaching, shared ideas about autonomy and support for professional initiatives of colleagues.

The results show the diverse nature of the teachers' development and changes in their practical knowledge. The concept maps helped to bring structure into aspects of teachers' practical knowledge and helped to make teachers' knowledge of concepts and the relationships between concepts explicit (Schvaneveldt et al. 1985; Van Gog et al. 2009). 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; van den Berg 2002), 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 enquiry-based teaching seems influenced by their practical knowledge, for example, about Group work or Statistical content. Annet and Christine emphasised 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; van den Berg 2002).

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'. Her concerns are seen as challenges to remove barriers 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. It is our impression that Bart and David needed more time to adopt novel teaching strategies. According to Timperley et al. (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 build the required pedagogical content knowledge, and to change their practice needed in educational reforms.

Our findings also demonstrate that teachers' efficacy beliefs are important in their further professional development and educational change (McDonald and Klein 2003). 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 learning outcomes for pupils and making a teaching design more efficient. It should be noted here that both Bart and David wanted to continue the enquiry-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.

In our study, we used concept maps, interviews and lesson observations to monitor teachers' work on a teaching design and to gain insight into the changes in the knowledge teachers activated when preparing lessons and in teachers' concerns. This has proven to be a fruitful combination of research instruments, but we wish to make some methodological comments. This study reveals that use of concept maps yields useful information about teacher change if used in combination with interviews and lesson observations. However, the meaning of changes in the nature or the number of concepts in the maps 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 more coherent view on the central theme in the initial concept map. 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 the concept maps

is limited. However, the overview serves as an excellent agenda for a subsequent discussion on the concepts 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' actions in the classroom, which served as addition to the information from concept maps and interviews, providing more details on their practical knowledge.

A comment can be made on the role of the facilitator. In this study, the facilitator was also the researcher, but it seems to us that this did not influence the contributions of the teachers during the network meetings. The facilitator had an organisational responsibility, by ensuring the continuity of the network meetings, a substantive responsibility by sharing literature on statistics education and a responsibility to moderate and streamline the group process and the developmental process. The facilitator did not interfere with content, form and implementation of the teaching design.

The results show that changes occur at different rates regarding teachers' views on lesson goals, teachers' efficacy in implementing the design and the concerns teachers have in giving up their traditional teaching. Based on these results, we wish to make some recommendations, which also can be useful for pre-service teacher training (see also Gellert and Gonzalez 2011). Firstly, the network environment helped teachers to exchange ideas and to discuss concerns. This helped teachers to switch to new pedagogies and led to the development of their practical knowledge. Secondly, our network was an environment characterised by both trust and challenge. In the network, teachers felt safe to reflect on their knowledge and experiences. This is important as change involves both teachers' emotions and teachers' knowledge and skills (Timperley et al. 2008). Thirdly, the facilitator had an organisational responsibility and moderated the discussions during the meetings, but gave the teachers the responsibility for designing the lessons in the way they wanted. The facilitator should be aware that teachers develop at different rates. The facilitator can give teachers more self-confidence by giving them examples of good practice, in order to remove concerns. Fourthly, we think that an important stimulating factor is the support by the school administration, for example, by giving the opportunity for 'joint work' in departments. 'Joint work' does not only lead to teachers' development, but it also contributes to a shared view on teaching.

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Notes on contributors

Martha Witterholt currently received her doctorate in Mathematics and Natural Sciences. Her thesis is titled "Mathematics teachers' development of practical knowledge: Learning to collaboriatiely design and teach inquiry-based statistics lessons". She is a teacher educator in mathematics and also a mathematics teacher in secondary education. Her research interests concern teacher professional development and pupils' research skills.

Martin Goedhart is full professor in mathematics and science education at the University of Groningen. Further, he is head of the appartment of education and director of the Master program of mathematics and science education. His expertise are conceptional and skill

development, academic literacy, mathematical reasoning and teacher professional development. Currently, he is involved in research projects on curriculum development in secondary physics education on acadamic writing and mathematical reasoning at university level, and the development of sustainable entrepreneurship in companies.

Cor Suhre is currently employed as a senior researcher in the teacher education department of the University of Groningen. His research interests include assessment of computational thinking in secondary education, the contribution of computer assisted instruction to improve problem solving in Physics and Mathematics and the professional development of teachers. Currently he is involved in instrument development research aimed at the assessment of critical and creative thinking skills in university degree programmes.

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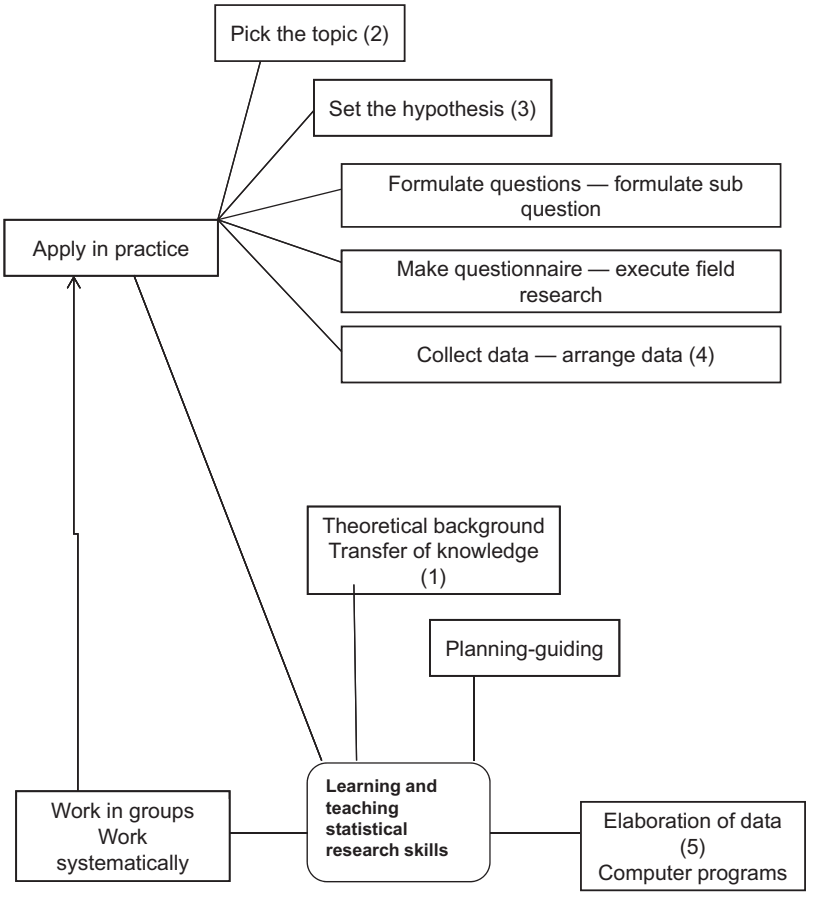
Appendix 1. Pre- and post-concept maps of Annet

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.



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.