6 General conclusions and discussion

6.1 Context and aims of the study

In the Netherlands, some major educational reforms in secondary education were implemented during the last twenty years. In order to modernize the curriculum, in 1993-1994 a new curriculum for the first three years of secondary education (In Dutch: Basisvorming) has been implemented. The aim of the Basisvorming was to prepare pupils better for their functioning in society. Therefore, pupils had to meet a number of established core objectives, to be realized by emphases on acquiring basic skills and content, indispensable for further development (see Wielemans & Vermeerbergen, 1990). An important principle of the Basisvorming is the emphasis on the application of knowledge, on the development of cognitive and social skills and on coherence between subjects, known as ‘Application, Skills and Coherence’ (in Dutch: TVS, Toepassing, Vaardigheden, Samenhang) (Harskamp & Suhre, 1997; Van Luyn, 1998). Therefore, mathematics teachers were expected to change their teaching methods and to develop skills to coach pupils in research projects, such as ‘integrated mathematical activities’ (in Dutch: Geïntegreerde Wiskundige Vaardigheden), which apply the TVS-characteristics and imply pedagogies like inquiry-based and collaborative learning (Roelofs & Houtveen, 1999). One of the core objectives for mathematics education in the Basisvorming is: "The pupil learns to systematically describe, organize, and visualize data and he learns to critically evaluate data, representations and conclusions”, which is in accordance with what is called statistical literacy. The ‘integrated mathematical activities’, where pupils gain experience in applying mathematics in realistic situations and in which pupils develop their skills, may be used to develop students’ statistical literacy.


In an educational innovation, such as the Basisvorming, where the context for teachers changes, teachers often need support and training. Although traditional forms of teacher training, such as one-day workshops, are quite common, they are widely criticized as being ineffective in providing teachers with sufficient activities and content necessary for
increasing teachers’ knowledge and fostering meaningful changes in their classroom practice (Loucks-Horsley et al., 1998). This study supports the view that teachers should be substantially involved in the preparation as well as in the evaluation and revision of any reform effort (e.g., Lynch, 1997; Parke & Coble, 1997; Van Driel, Beijaard & Verloop, 2001). The role of teachers in the context of curriculum change should not be limited to ‘executing’ the innovative ideas of others, like policy makers, curriculum designers or researchers (Van Driel, et al., 2001), as active teacher learning involves the opportunity to link the ideas introduced during professional experiences to the teaching context in which teachers work (Garet, Porter, Desimone, Birman, & Yoon, 2001). Much of what teachers need to learn must be learned in and from practice (Hamermesh, Darling-Hammond & Bransford, 2005), and well-designed professional training helps teachers to realize sustainable changes (Darling-Hammond, Chung Wei, Andree, Richardson & Orphanos, 2009).

In teacher training it is important to know what the gap is between the existing teaching behavior and the required behavior that fits into the innovation. Generally, before the Basisvorming, mathematics teachers had little or no experience in developing and implementing research projects. Now, they were expected to introduce inquiry-based teaching as a pedagogical approach that invites students to explore content by posing, investigating, and answering questions (see National Research Council, 1996).

This dissertation explored mathematics teachers’ development of practical knowledge during the process of the introduction to inquiry-based teaching, by designing a teaching strategy, in which 7th grade pupils developed their statistical literacy by conducting statistical research. Fenstermacher (1994) referred to ‘practical knowledge’ as the knowledge teachers themselves generate as a result of reflections on their experiences. In her study, Meijer (1999) used Fenstermacher’s idea of practical knowledge as a starting point, referring to the cognitions that underlie teachers’ actions. Thus, in her conceptualization of practical knowledge, she considered teachers’ knowledge and beliefs. In my study (see chapter 3), teachers’ practical knowledge is defined as ‘the knowledge, skills and beliefs teachers use to practice their profession’. My study relies on the categories of teachers’ practical knowledge of Meijer (1999, p. 49, 61), adapted for statistics education. I distinguish:

1. Subject matter knowledge: knowledge of statistics (see also Sowder, 2007)
2. Student knowledge: 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

Park and Oliver (2008, p.263) described that four commonalities have consistently appeared in the domains of teacher knowledge: pedagogical knowledge, subject matter knowledge, pedagogical content knowledge (PCK), and knowledge of context. In their study, Ball, Thames and Phelps (2008) examined the work of Shulman (1986a, 1987). Shulman’s work was based on general dimensions of teacher knowledge, like pedagogical knowledge, and on content-specific knowledge, like subject matter knowledge. Shulman focused on the latter types of knowledge. He argued that knowing a subject for teaching requires more than knowing its facts and concepts. PCK has been described as the knowledge used to transform subject matter content into forms more comprehensible to students (Shulman, 1986b, 1987; Grossman, 1990; Marks, 1990) and PCK concerns the teaching of particular topics and refers to a transformation of the subject matter knowledge, used by teachers in the communication process with learners (Van Driel, et al., 2001). Park and Oliver (2008, p.264) redefined Shulman’s definition of PCK by: ‘PCK is teachers’ understanding and enactment of how to help a group of students understand specific subject matter using multiple instructional strategies, representations, and assessments while working within the contextual, cultural, and social limitations in the learning environment’.

In Shulman’s categorization (1987), the above-mentioned categories 3 and 6 can be considered pedagogical content knowledge (PCK). After Shulman’s introduction of PCK, Grossman (1990) considered the categories 4 and 5 also as PCK. Category 2 is similar to what others have called ‘knowledge of context’ (Magnusson, Krajcik & Borko, 1999). According to Shulman (1986a) and Sowder (2007), teachers should acquire novel practical knowledge, like PCK and curricular knowledge, and possibly subject matter content knowledge in order to keep up with innovations in education. Furthermore, Bandura (1986) argued that self-efficacy beliefs – individuals’ judgments of their competence to execute a particular task – are the strongest predictors of human motivation and behaviour. Therefore, teachers’ confidence to perform specific new tasks (self-efficacy) is also of interest.
In this study, four teachers of the same school volunteered in a professional development trajectory, spread over two years, where they developed, implemented and evaluated a teaching design for 7th grade pupils during network meetings. A main purpose of such a trajectory is to give teachers a hold for pedagogical decision-making (see Van den Heuvel-Panhuizen & Wijers, 2005) and for sharing responsibility and authority (Imants, 2003). For teachers, this means, for example, that they reflect on subject matter, on teaching strategies, on testing pupils and on pupil collaboration, during which they reconsider their own knowledge and skills (see Shulman, 1986a).

The purpose of my study was to investigate how teachers react and behave when they acquire novel practical knowledge and to show how teacher development proceeds. Preliminary research (see chapter 2) showed that teachers found it difficult to supervise and guide groups of 9th grade pupils, when implementing a design for teaching statistical literacy. They also found it difficult to distance themselves from their usual central role. The teachers found that the regular written tests were not appropriate in this case, as the learning process also had to be assessed. Therefore, different assessment procedures of pupil work were necessary. This included, for example, assessment through logbooks and posters instead of written tests.

The main research question of this dissertation is: How do mathematics teachers develop their practical knowledge when collaborating on the design and implementation of an inquiry-based teaching strategy on statistics for lower secondary pupils? In order to answer the research question, I report on a trajectory for the professional development of a small group of mathematics teachers. The professional development trajectory in this study is designed according to ideas of ‘joint work’ (see chapter 5; Little, 1990). Principles of the trajectory in this study are: (1) Teacher development is considered as a long-term process (Fullan, 2001). Therefore, the professional development trajectory in this study was spread over two years; (2) The trajectory builds on collegiate commitment in order to increase the collective efficacy of the group (Fullan, 2001; Jackson & Bruegmann, 2009); (3) The trajectory is related to teachers’ classroom practice, because it is known that all successful strategies are socially based and action-oriented (Fullan, 2001; Putnam & Borko, 2000); (4) Realistic experimentation with new pedagogic forms of working is undertaken; (5) Reflection on what works and does not work is essential (Wilson & Berne, 1999).

Network meetings provide the basis of this professional development trajectory. The network meetings, in which a small group of mathematics teachers of the same school participated, were led by the researcher who acted as facilitator. During the network meetings, the main task of the teachers was developing an inquiry-based teaching design for 7th grade pupils.
They discussed the design and implementation of statistical research tasks, until they reached consensus. After the design process in network meetings, the teaching design was implemented. In the last network meeting, teachers evaluated the design and learning results of pupils. In order to achieve the above-mentioned goals, the network of teachers had to provide a safe environment for teachers to collaborate and exchange thoughts and ideas.

In my research, I used The Interconnected Model of Teacher Professional Growth (ICMTPG, Clarke & Hollingsworth, 2002) to guide my investigation, see Figure 6.1.

![Figure 6.1: An operationalization of The Interconnected Model of Teacher Professional Growth](image)

In short, experiences in the classroom [DoP], which are derived from the external domain [ED] and from teacher’s practical knowledge [PeD], lead to salient outcomes in the domain of consequence [DoC], which influence teacher’s practical knowledge. Change in one domain is translated into change in another domain through the mediating processes of reflection (dotted arrows) and enaction (solid arrows). Reflection is the ability to look back on an experience in a structured manner and to draw conclusions for future actions (Korthagen & Vasalos, 2009). Enaction is not only ‘action’ but, more strongly, each action represents a confirmation of something a teacher knows, believes or has experienced (Clarke & Hollingsworth, 2002, p.951). The external domain [ED] can be interpreted as the initiator of
professional development. In my study, the network meetings serve to exchange knowledge and experiences, which will often trigger reflection on each other’s teaching practice and ideas. The key ingredient of the domain of practice [DoP] is teachers’ experimenting in their classrooms, in particular the implementation of the teaching design and teachers’ behavior during the lessons. Change in the domain of consequence [DoC] is firmly tied to the teacher’s existing value system and to the inferences the teacher draws from the practices of the classroom. Clarke and Hollingsworth (2002) mention as an example that using a new teaching strategy can have a positive outcome for one teacher, but a feeling of loss of control for another teacher. This domain is therefore coloured by teacher’s expectations and can be described as new conclusions drawn by the teachers with respect to their classroom practice. The personal domain [PD] consists of teachers’ practical knowledge, including knowledge and beliefs. In section 6.2 I will return to this model.

The development of teachers’ practical knowledge was established by using a number of instruments. I used concept maps, semi-structured interviews, lesson observations and transcripts of network meetings to identify crucial aspects of teachers’ development of practical knowledge. In the school year 2006-2007, one cycle of developing, implementing and evaluating the teaching design was spread over six months. In the school year 2007-2008, the same cycle was carried out, with the difference that the first design was improved by a group of two different and one the same mathematics teachers of the same school. I collected concept maps, conducted semi-structured interviews, transcribed network meetings and made lesson observations in both years, but the first group yielded so many data that I largely have limited my study to this group.

6.2 Conclusions

In this section I will briefly discuss the four studies that were conducted, described in the chapters 2, 3, 4 and 5, and the conclusions that were drawn.

6.2.1 Conclusions from the different studies

The first study, described in chapter 2, is an exploratory study to inform me which skills teachers need to develop to be able to engage in inquiry-based teaching. The study was also necessary in order to obtain information about the skills pupils need. It was important to
know whether or not teachers and pupils lacked knowledge and skills to guide or perform research assignments. The study focused on 9th grade pupils and the way they performed statistical research. For that purpose, an introductory assignment was developed, where pupils followed an investigative cycle under supervision, based on a given problem definition. The intention was also, that some statistical concepts were introduced during the work on this assignment, like the mean, mode, median, correlation and representative sample. Furthermore, a statistical research assignment was designed by me and I also determined characteristics of the teaching of statistical literacy from literature (McClain & Cobb, 2001; Bakker & Gravemeijer, 2002; Bakker, 2004; Doerr & English, 2003; Chance, 2002). The assignment demanded that pupils had to go through a well-defined investigative cycle (Millar, 1989; Wild & Pfannkuch, 1999; Pijls, Dekker & Van Hout Wolters, 2000; Van Rens & Dekker, 2000), which meant that they started with defining a problem and formulating the research question, to interpreting their results, using their previously acquired statistical knowledge. The research assignment had an open character: pupils chose their own topics, research questions, data collection methods, and reporting of results. The condition was that pupils had to find a correlation between two variables. By way of learner reports, which is an instrument to collect information on the pupils’ progress and performance (Schenke & Galjaard, 2010), pupils reported on what they have learned. With help of learner reports, pupils should become more conscious, not only of the problems that may occur when independently conducting research, but also of their own strengths and weaknesses in this field (see Wild & Pfannkuch, 1999). Teachers guided groups of pupils when performing the research task.

I found that some aspects of the implementation of the research assignment went better than others. As positive aspects of the first study I identified that pupils acquired sufficient knowledge of statistical concepts and graphical representations. They were able to calculate measures of centre (like mean and mode) and they were able to draw various different graphical representations, such as pie and bar charts with or without the help of a statistical computer program like VU-Statistiek or Excel. The investigative cycle served as guidance for pupils. They conducted their research by formulating their own research questions, drawing up a research plan, drawing conclusions and looking back on the problem. By means of learner reports, pupils indicated their own development with regard to relevant skills, like ‘Task distribution’, ‘Making agreements’ and ‘Keeping agreements’ with regard to working in groups, and skills used for statistical purposes, such as ‘Collecting data’, ‘Processing data into a story’, ‘Completing a written assignment’ and ‘Giving a presentation’. Pupils indicated
in the learner reports that they enjoyed doing research and that they would like to do this more often. They indicated that what they enjoyed most about the project was working together with their classmates.

In the first study, I found that a few things went different than intended. Although pupils acquired sufficient knowledge of statistical concepts, this knowledge appeared to be isolated. In the context of conducting statistical research, pupils were able to calculate the mean, mode and median, but they could not decide when to use which measure of centre. Furthermore, the preparatory phase did not sufficiently prepare pupils to apply their statistical knowledge and concepts, to interpret measures of centre, to correlations between variables and to keep a log book. Finally, teachers did not put sufficient emphasis on metacognitive skills of pupils, and they did not monitor the process by checking pupils’ log book and checking pupils’ research questions on suitability.

Although the teachers were pleasantly surprised by the dedication and motivation demonstrated by their pupils, the nature of the problems that occurred shows that teachers had difficulties with how to monitor and regulate pupil learning. For example, teachers should have provided more guidance in the pupils’ choice of topic and should have intervened sooner if a research question was limited to a calculation problem. Pupils should be encouraged to fill in a log book, because this encourages them to think about appropriateness of their actions. But most teachers had no experience in supervising research projects.

In conclusion, the first study gave a format for an intervention to train teachers to apply inquiry-based teaching. In this format, teachers must learn to control and regulate pupil learning, which emphasizes that teachers must learn to develop skills in guiding research assignments. Therefore, teachers should place sufficient emphasis on metacognitive skills of pupils and their feedback should focus on finding suitable research questions, aimed at finding a correlation between variables. Furthermore, teachers should learn pupils to work on the basis of the investigative cycle, including filling in the log book, which helps pupils to monitor the research process. Furthermore, teachers must learn to support pupils’ development of statistical literacy by identifying critical phases in assignments and asking the right questions at the right time. Although the pupils were able to calculate measures of centre and draw graphical representations, they did not always draw the right conclusions from their research. As pupils of the 9th grade were already introduced to statistical concepts in the 7th grade, more attention should be paid in applying these concepts. According to Van der Sanden, Terwel & Vosniadou (2000) concepts can develop during the research process,
instead of being presented in advance. This way, concepts are addressed when pupils ask for it. However, this requires a different teaching approach.

The above shows that teachers may benefit from a professional development trajectory with special emphasis on encouraging pupils to work together, teaching pupils statistical literacy and explicitly paying attention to metacognitive skills.

In order to support mathematics teachers in guiding research assignments, I designed a professional development trajectory anchored in peer collaboration, which I called a network. The second study, described in chapter 3, investigated four mathematics teachers of the same school who were introduced to a new pedagogical approach to teaching statistics through inquiry-based teaching. During the course of network meetings, based on ‘joint work’ (Little, 1990), and implementation of the newly and jointly designed statistical teaching strategy for 7th grade pupils, I aimed at revealing how teachers changed their practical knowledge by means of data from interviews, concept maps and classroom observations.

The combination of drawing concept maps and discussions of concept maps provided me with information about teachers’ profiles and a comparison of the teachers’ initial (before the intervention) and final (after the intervention) practical knowledge. Two important conclusions can be drawn from the second study. Firstly, three of the four concept maps became more pupil-centred after the intervention, instead of being more teacher-centred before the intervention. Secondly, the teachers differed in the concerns they raised during the intervention, and correspondingly, they developed at different speed. I found how the nature of the teachers’ development was dependent on their practical knowledge, for example, about ‘group work’ or ‘statistical content’. Two teachers, 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. Two other teachers, Bart and David, were primarily concerned to teach statistical knowledge, possibly conditioned by the textbook.

Changing their teaching practice raised new concerns among these teachers. Individual differences depend on teachers’ practical knowledge and beliefs, and especially concerns are crucial.

I found that our experienced teachers had what Fuller (1969) called ‘late concerns’, which may be positive or negative. It seemed that negative teacher concerns are linked to an approach in which ‘subject matter’ is predominant. For example, David raised many concerns, particularly after the intervention. He was rather negative about the outcomes of the lessons, as he stated after the intervention about pupils: ‘Now I saw pupils struggling with
problems on the self-chosen research questions I interpreted as: Either too ambitious or too simple’, and about group work: ‘the size of the groups depends on the guidance. I believe there are too many groups to help all at once’. These concerns dominated thinking of these teachers and hindered them from further experimenting in their practice. This may be the reason that, although practical knowledge underlies teachers’ actions, I determined with the instruments used that for some teachers there is clear agreement between their practical knowledge and their observed teaching practice, while for others this is not the case. The point is that teachers may use experiences in a positive way and show that they have learned from their experiences. I also concluded that, although networks are considered as effective in influencing teachers’ efficacy beliefs (McDonald & Klein, 2003), I was not successful in realizing an effect on efficacy beliefs with all of the teachers participating in the network. It was my impression that, although there are some differences in their initial and final practical knowledge (see chapter 3), some teachers needed more time to adopt novel teaching strategies, but they were willing to experiment with it again.

In the third study, described in chapter 4, I aimed at identifying the interrelation between successful implementation of novel teaching strategies and changes in practical knowledge. I used the Interconnected Model of Teacher Professional Growth (ICMTPG) (see figure 6.1) of Clarke and Hollingsworth (2002) as a means to describe the process of professional development (see also De Jong, Van Driel & Verloop, 2005; Anderson & Moore, 2006). The essence of the model for my study was to describe cycles of teacher change. Chains of events from the ICMTPG were used to represent changes in teachers’ practical knowledge. In a single case study with one teacher who showed most progress, Annet, I found that changes originated from the implementation of the teaching design in the classroom by means of discrepancies between expectations and experiences. Reflection on the formulated expectations during the network meetings and during and after the lessons resulted in development of practical knowledge during a process of two years. Applying cycles of change from the ICMTPG provided an explanation of our findings: the teacher’s practical knowledge changed in the personal domain. Controlled experimentation and reflection were necessary conditions to learn a new teaching strategy and to develop a series of lessons for pupils. The third study showed a few essential components in my approach:

1. The network approach was effective as Annet was able to tailor her teaching and design to the requirements of her pupils, and to adapt her actions more to the
classroom context. In other words, she showed flexibility. This is an extension in practical knowledge in the category 'Knowledge of context'.

2. Enactment of teaching practices and reflection on experiences from the classroom had been a major ingredient of the network meetings. Processes of reflection and enaction are prerequisites for learning and these processes have to become ingrained in teachers’ daily practice.

3. In round 1 the arrows describing the process of teacher change are mainly 2, 1, 5, 3, 7, 8 and 9 (see Figure 6.1). In round 2 the process may be described by the arrows 2, 4, 6 and 8 see (Figure 6.1), which means that thanks to the growth of Annet’s practical knowledge, her enaction became more explicit. In the first round, arrow 2 was not yet firmly developed, but in round 2 Annet’s contribution to the network meetings was stronger.

The positive effects of the network approach gave rise to further exploring the decision-making process. The fourth study, described in chapter 5, focused on the discourse in discussions in the network of four mathematics teachers, in order to explore stimulatory and inhibitory factors. Therefore, I analyzed transcripts of network meetings on statements that indicated decisions and on statements that contributed to the decision-making. The most frequently discussed themes were: teaching goals, assessment and group work. Teachers engaged in discourse and reached consensus, and the discourse showed teachers’ development of practical knowledge on teaching goals, assessment and group work. My analysis of the transcripts of the network meetings revealed that while teachers changed their teaching they also experienced common difficulties in the implementation of the teaching design.

Since the development of practical knowledge differs per teacher, I will give an overview of the most important findings of the fourth study. Regarding the teaching goals, the most interesting development was that teachers made a switch from statistical skills to statistical literacy. This implies that teachers focused more on pupils’ research projects and the development of pupils’ research skills than they did before. However, it is important to note that statistical skills are a requirement for statistical literacy (see also Rumsey, 2002). Teachers found it hard to find criteria how to assess statistical literacy. This is suggested by Annet’s statement “I think they have learned a lot, but it’s all a bit vague what exactly”. This lack of criteria leads teachers to abandon the criteria they used in their regular teaching practice, that is with a traditional knowledge test. About group work, the results were found
disappointing by the teachers and especially by Bart. Generally, pupils found it difficult to cooperate and teachers had the feeling of losing control in the classroom. However, except for Bart, the teachers still had a positive stance towards group work. It is my interpretation that teachers see the benefits of group work but that they lack skills and, some of them, confidence to organize it in a proper way and to assess pupils’ learning.

I found how a collegial network stimulated teachers to cross the line of new pedagogies, even if individual teachers did not have a drive to change (see also Jackson & Bruegmann, 2009). Collaboratively working on a statistical teaching design and jointly reflecting on what happened in the classrooms provided a focus to the discussions. Working together was valuable for the teachers: conservative professionals and progressive professionals complement each other (Clement & Vandenberghe, 2000). Although these are different types of professionals, they both strongly contributed to the decision-making process. Distinction can be made between ‘involvement in’ and ‘contribution to’ decisions (see chapter 5 for a full description). In short, conservative professionals ask questions and progressive professionals devise arguments for the selected (and agreed upon) route. It is essential that the coaching strategy should ensure that, within the school, both types of professionals feel free to discuss their ideas and do not have reservations to put forward suggestions. Otherwise, conservative professionals can become reactionary, restricting themselves to their own classroom practice.

6.2.2 Answers to the main research question

The main research question of my study is: ‘How do mathematics teachers develop their practical knowledge when collaborating on the design and implementation of an inquiry-based teaching strategy on statistics for lower secondary pupils?’.

Although this question asks for the factors influencing the teachers’ development, I first give an overview of what practical knowledge teachers learned during the trajectory. Combining the findings from the chapters 3 to 5, we can draw following conclusions on their development. An important change in teachers’ PCK is that teachers realized that pupils do not need to understand all statistical concepts before they start a project but, instead, that students’ understanding of statistical concepts can be developed gradually during the project. This is a remarkable shift in thinking, because teachers did not consider inquiry as an application of statistical concepts any more, but as a context in which students can develop their statistical literacy. We found that teachers were more willing to re-examine their knowledge and beliefs on teaching goals (especially, statistical literacy), than on group work and assessment. Regarding group work, teachers were unwilling to relinquish their autonomy.
in the classroom, which is inevitable for group work and also for inquiry-based teaching. On the other hand, they developed skills to guide groups of pupils during conducting their own research. Regarding assessment, teachers found ways to assess the posters, made by the pupils. However, teachers also fell back on a traditional written test, despite their original plans to only use a more innovative assessment with a poster created by the pupils. It seemed that their beliefs prevented them from this way of assessment. Especially, efficacy beliefs may play a role here, as teachers do not believe in their own abilities to use other assessment methods.

Although teachers developed their knowledge of statistics, of the teaching of statistics and of inquiry-based teaching, it became clear that teachers’ development and the changes in their practical knowledge are diverse. Firstly, teachers develop at different speed as one teacher needs more time to adopt novel teaching strategies than others. Secondly, two teachers, Bart and David, tended to fall back on old habits, like traditional instruction and assessment methods. All teachers, however, wanted to continue to work in the network, so they had to come near each other. Consensus was reached about the content of the teaching design, but teachers still did not have all the answers for guidance and organization of the process in the classroom.

The factors that affected teacher change can be divided into two groups: the knowledge and beliefs of the participating teachers, and the way the network meetings were organized. First, I have identified factors that were related to teachers’ knowledge and beliefs. Teachers’ knowledge and beliefs have been shaped by their previous experiences. In some of the network meetings we found how these former experiences affected the discussions and decisions made in the network. I also found how teachers’ knowledge and beliefs led to expectations on the successes and failures of the design. Especially, teachers negative expectations (concerns) played a role in the way some of teachers participated in the discussions, implemented the design and judged the outcomes of the implementation of the design.

Teachers evaluate and develop their own practical knowledge by means of comparing expectations with experiences (arrow 3 in figures 6.1 and 6.2). For example, in chapter 4 I found that the most important changes in Annet’s practical knowledge originated from encountering discrepancies between expected and actual pupil behavior. During the implementation of the teaching design in the classroom, she experienced that pupils did not work together very well, and she was surprised about that (arrow 3 in figure 6.1). She
underestimated the problems pupils had when working together in groups. However, she was convinced that pupils learned different things by working in groups, and ‘I don’t think they learn that by just working with the textbook’, which was her new conclusion. Bart, however, perceived the problems during the group work differently (see chapter 3). He said that the trajectory was quite demanding for him. After the implementation of the teaching design he repeated his (task-based) concerns, which were apparently confirmed by his experiences during the lessons. However, the lesson observations did not reflect these doubts. He indicated that ‘the pedagogical part is rather difficult’, but this was not apparent in the lesson observations. He asked pupils questions to guide them adequately through the research phases, and pupils were animated and motivated in their work. For him, the results of the implementation was a confirmation of the concerns he had beforehand, and his conclusion was that pupils would have learned more if he had given them traditional instruction. Thus, the ways in which mathematics teachers develop their practical knowledge are diverse, depending on their concerns, which emerge from their previous teaching experiences.

Figure 6.2 as a part of figure 6.1, which represents an operationalization of the ICMTPG, can be used to emphasize the role of concerns.

Figure 6.2: A part of the ICMTPG to emphasize the role of concerns

In figure 6.2, concerns play a role in the arrows 6, 7, 8 and 9. The domain of consequence [DoC] is teachers’ personal frame of reference. The development of beliefs (and concerns) may occur through this domain. Arrow 7 represents the reflection on salient outcomes of the events in the classroom and teachers’ new conclusions regarding these events. Arrow 8 represents the use of practical knowledge to model newly acquainted conclusions drawn from new classroom experiences. Arrow 9 represents the reflection on the constituted outcomes of
the teachers’ exploration of a new teaching strategy, leading to changes in teachers’ practical knowledge.

Arrow 4 represents the enaction of teachers’ practical knowledge in the classroom as a regular feature of teachers’ practice. Arrow 3 represents teachers’ reflection on classroom events. This is similar to the reflection represented by arrow 7. The difference is that the process represented by arrow 3 involves less dramatic changes in practical knowledge, for example, knowledge about pupils. This latter process involves extensions of teachers’ routine knowledge and do not directly affect their deep-rooted beliefs on teaching.

For teachers who are not open to educational change, innovation can only be successful if they change their belief system. When implementing an innovation, the teacher should experiment in the classroom. He must weigh what he finds important and abandon the secure environment. If this change leads to negative experiences, the teacher is likely to revert to his ‘old’ practical knowledge and his concerns may be enforced. If the change leads to positive experiences, the teacher is likely to integrate these experiences into his practical knowledge.

The way teachers value experiences is determined by the domain of consequences, related to his practical knowledge. This valuation is also influenced by the network. Colleagues bring in their interpretation of their classroom experiences and these influence the interpretations by individual teachers. Thus, the network might compensate for individual negative experiences and may result in changes of teachers’ beliefs. In a network environment individual beliefs become part of a network belief system.

As a result of my study, I identified some factors affecting the successfulness of the network. First, the network activities were structured by the common design task. Research has shown that many of the best learning experiences emerge when humans are engaged in designing and creating things, especially things that are meaningful either to us or to others around us (e.g., Papert 1993, Resnick, 2002). By means of controlled experimentation, which evaluates an idea by implementing it (Papert, 1993), my study provided a good learning experience for the teachers. Evaluation of the teaching design gave teachers indications on what did and did not work for their pupils.

Teachers’ engagement and commitment was an important factor. It appeared that the commitment of the participants to the group and consequently to the teaching design was strong and, as indicated above, strongly influenced teachers’ development. Teachers reached consensus during network meetings on the content and implementation of the statistical teaching design. During network meetings, they performed their tasks as agreed upon. From
lesson observations it appeared that teachers acted in accordance with the agreements reached during network meetings.

The role of the facilitator is particularly important, as the facilitator gave structure to the network meetings and she monitored the development and evaluation process of the statistical teaching design. This means that the facilitator had an organizational 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, however, did not interfere with content, form and implementation of the teaching design in order to increase teachers’ motivation and dedication to the developed statistical teaching design.

Another influence on teachers’ development concerns the prolonged character of the network meetings. Desimone (2009) mentioned that intellectual and pedagogical change requires professional development activities to be of sufficient duration, which shows support for activities that are, for example, spread over a semester and include 20 hours or more of contact time. The intervention took a period of two years and in one year network meetings were spread over 6 months, and one network meeting took at least 50 minutes.

Another important factor is that the network environment should be sufficiently safe, so that teachers are not afraid to be open and could appeal if they did not agree with someone else. Lieberman & Pointer Mace (2010) mention about Little’s (1982, 1986) work that teachers who planned and worked together over time built commitment not only to each other but to further learning. Even the act of “struggling” together at the same time in the same ways helped teachers to master new practices.

6.3 Practical knowledge and teacher change

In my study I use the term ‘teachers’ practical knowledge’. This is a comprehensive concept, as it includes in our study teachers’ knowledge, beliefs, skills and attitudes (see Jones & Carter, 2007). There is no agreed-upon distinction between knowledge and beliefs in research in teachers’ knowledge (Borko & Putnam, 1996). In chapter 1, I defined practical knowledge as ‘the knowledge, skills and beliefs teachers use to practice their profession’. Pajares (1992) found that beliefs were defined as being based on evaluation and judgment, while knowledge is based on objective fact. Moreover, beliefs have both affective and evaluative functions, acting as information filters and impacting how knowledge is used, organized and retrieved (Gess-Newsome, 1999). Beliefs, next to other factors, do influence how teachers perceive and
enact their roles in the classroom. According to Clement (1999), knowledge is ‘belief with certainty’. Philipp (2007, p.267) describes the distinction as follows: "A conception is a belief if a person could respect a position that is in disagreement with the conception as reasonable and intelligent, and it is knowledge if the person could not respect a disagreeing position with the conception as reasonable and intelligent. Under this definition, one person’s belief may be another person’s knowledge”. Although there is no clear linear relationship between the development of beliefs and the amount of practice (Cross, 2009), behavior can only be changed when beliefs are discussed (Stipek, Givvin, Salmon & MacGyvers, 2001).

In my study knowledge, beliefs and attitudes are not always separated, but my study shows the importance of beliefs in teacher change. When teachers gain evidence of improved student learning and see that a new program or innovation works well in their classrooms, change in their attitudes and beliefs may follow (Guskey, 2002).

According to Ernest (1989), two factors affect beliefs during their transformation into practice: (1) the constraints and opportunities of the social context of teaching, which results from the expectations of others including students, parents, colleagues and superiors, and (2) the teacher's level of consciousness of his or her own beliefs, which is related to the extent to which the teacher reflects on his or her practice of teaching mathematics. Ernest mentions that some of the key elements in the teacher's thinking, and its relationship to practice, are the following:

- Awareness of having adopted specific views and assumptions as to the nature of mathematics and its teaching and learning.
- The ability to justify these views and assumptions.
- Awareness of the existence of viable alternatives in teaching strategies.
- Context-sensitivity in choosing and implementing situational appropriate teaching and learning strategies in accordance with his or her own views and models.
- Reflexivity: being concerned to reconcile and integrate classroom practices with beliefs; and to reconcile conflicting beliefs themselves.

Looking at the above points, the network environment in this study gave teachers the opportunity to express and reflect on their beliefs, to compare and justify their beliefs, to become aware of alternative beliefs and to design a teaching strategy in accordance with their beliefs. Sometimes, this meant that teachers adapted their beliefs, as existing beliefs were not appropriate anymore.
As indicated, in my study teachers developed their practical knowledge. In the research setting, I clearly can make a distinction between the extent in which teachers adapt to a new teaching pedagogy. Some teachers have difficulties in adapting their beliefs to new pedagogies of teaching, which points at an interaction between teacher beliefs, and especially concerns, and teacher professional identity. My study shows that experiences do not always lead to changes in practical knowledge, as teachers interpret experiences through the filters of their existing knowledge (cf. Putnam & Borko, 1997). Beijaard, Meijer and Verloop (2004, p.123) noticed that identity formation is a process of practical knowledge building characterized by an ongoing integration of what is individually and collectively seen as relevant to teaching. According to Canrinus, Helms-Lorenz, Beijaard, Buitink and Hofman (2011, p.594), teacher professional identity generally pertains to how teachers see themselves based on their interpretations of their continuing interaction with their context. For instance, Bart sees himself different than how he has been perceived by the researcher during his lessons (see section 6.2). The network in this study did not fully succeed in having a positive effect on Bart’s efficacy beliefs, such as taking away his concerns. However, Bart agreed to join the network meetings in the next year despite his concerns (see chapter 3). Canrinus et al. (2011) mention the following indicators for teachers’ professional identity: job satisfaction, self-efficacy, occupational commitment and change in the level of motivation. These constructs are often described in the literature as being important to teacher behavior and they represent a personal perspective on how teachers view themselves as professionals in their work. As I did not always find a direct correspondence between teaching practices and practical knowledge, I draw the conclusion that teaching practices are not only determined by a teacher’s practical knowledge but also by his professional identity. In my study, important components of professional identities are, for example, perseverance, willingness to experiment and be able to deal with disappointment.

6.4 Reflection on research methods
I used several research instruments to identify teachers’ practical knowledge and each research instrument has contributed to this identification. Through concept maps and discussions in combination with semi-structured interviews, I was able to explore and analyze teachers’ practical knowledge in a detailed way. This stands in contrast to the literature, which is rather sceptical about the use of concept maps in revealing teachers’ practical knowledge (see Meijer, 1999; McClure, Sonak & Suen, 1999). My experience is that concept maps combined with individual interviews about the concept maps may be a useful research
instrument, especially when comparing teachers’ concept maps before and after an intervention, as the first concept map served as a reference. A strong point of the combination of concept maps and subsequent interviews is that concept maps give rise to talk about goals, content, form and assessment of – in my case, statistics – education. If the concept maps are taken as the starting point, it forces teachers to reflect on their practical knowledge, which provides insight into their knowledge and beliefs.

The discussions during network meetings represented the process of teachers’ decision-making. I got insight into the changes of teachers’ practical knowledge by comparing teachers’ statements during the design phase (the first six network meetings) with the evaluation phase (during the seventh meeting). Transcripts of network meetings, concept maps and transcripts of the discussions of concepts maps and interviews, enabled me to get insight into the development of the teachers and construct cycles of change from the Interconnected Model of Teacher Professional Growth. In my study, lesson observations supported the other data sources, especially the discussions of concept maps and the semi-structured interviews. Lesson observations were conducted to indicate teacher behaviour during the implementation of the teaching design. I have observed each lesson of all the teachers, but I could have used the lesson observations more intensively. For example, to validate my conclusions on teachers’ practical knowledge. Another option is to use video recordings along with stimulated recall interviews, letting teachers explicate their decisions in response to watching the videotape of a lesson they have just given (cf. Calderhead, 1981; Lyle, 2003). In this way, for example, I could have checked how teachers’ individual decisions in the classroom relate to the agreements made during the network meetings.

I collected qualitative data, because I needed a detailed exploration and understanding of teachers’ practical knowledge. This resulted in in-depth information about the development of the mathematics teachers. The effects found are not generalizable, but it is important to realize that the school context in which teachers work is taken into account in this study. The school context may stimulate or hamper the collaboration between teachers. These local conditions within schools are essential for the success of professional development, especially when following the ‘joint work’ strategy in this study. The challenge of enhancing teacher professionalism is, significantly, a local matter. Quantitative large-scale research studies tend to neglect these local differences between schools. As Nastasi and Schensul
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(2005, p. 187) note: “qualitative methods can help researchers to describe various manifestations of intended outcomes that may not be reflected in standardized instruments and to identify unintended positive or negative outcomes for the individual and institution/community.”

6.5 Recommendations for teachers’ professional development

In this study, teachers collaborated in a network of colleagues on a teaching design for 7th grade pupils. This is an effective form of professional development, as my study shows that in such teacher networks social commitment is large. Teachers participated, sometimes in solidarity with colleagues, and they subsequently got caught up in the development process. My research provided insights into stimulating and inhibitory factors for teachers’ development. In arranging network meetings for teachers, I have a number of recommendations concerning the organization of the network meetings, the role of the facilitator and the school context.

Regarding the network meetings, my recommendations are:

1. An essential element of the professional development trajectory is that teachers collaborated on a teaching design, which was also implemented. In this way, there was a clear, common goal and the trajectory was linked to their daily teaching practice. Teachers designed teaching materials by exchanging experiences and knowledge. In the design process, they discussed pupils’ prior knowledge, structure of learning materials, teaching objectives and testing methods.

2. The network of teachers should guarantee an environment where all types of teachers feel free to discuss their ideas and do not have reservations to put forward suggestions. Positive collegial relations ensure commitment to the network and to the collaboratively developed teaching design. Thus, the network gives teachers ample opportunities to discuss their knowledge and beliefs.

3. Teachers should use resources, like research literature, in the process of developing the teaching design in order to get knowledge of the subject matter content and domain-specific pedagogies.

4. Teachers should articulate their personal development goals at the start of a professional development trajectory. If clear learning objectives have been formulated, it can be determined whether they are met at the end of the trajectory. Otherwise, interim adjustment may be possible.
5. In my study, teachers evaluated the teaching design during an evaluative network meeting. The facilitator lost sight of the teachers during the implementation of the teaching design, in particular concerning practical issues that arose during the implementation phase. As an improvement of the professional development trajectory, I recommend that teachers should meet for intermediate collegial consultation in order to discuss interim problems during the implementation of the teaching design. For example, they may try to take away existing or arising concerns during the implementation phase by reflection on action.

6. It is also recommended that teachers visit each other’s lessons during the period of implementation of the teaching design, to see how the lessons of colleagues proceed. Afterwards, an evaluation of the lesson may take place. Further, the use of video recordings of lessons could have offered opportunities to evaluate the teaching design and its implementation during the network meetings.

During the network meetings, the facilitator has an important role. My recommendations on the facilitator’s role are:

1. The facilitator leads the network meetings and provides a focus to the discussion, creates and gives support to teachers, summarizes decisions, establishes appointments, structures and monitors network meetings. However, the ownership of the process should be in the hands of the teachers. The facilitator should keep distance when it comes to drawing up form and content of the teaching design;

2. The facilitator provides teachers with resources at the proper moment. Resources could be examples of teaching materials (instructional materials, computer software, examples of tests) and research literature. By giving examples of good practice, the facilitator may remove objections raised by the teachers and could give teachers self-confidence;

3. The facilitator can take away unpleasant emotions, such as disappointment and frustration perceived by the teachers as roadblocks on the path to achieving their goals (Cross & Hong, 2012).

The school context should not be prohibitive, but should invite teachers to develop their professional expertise. The school management has a responsibility in supporting this kind of professional development and should stimulate teacher collaboration. These teams should be composed in such a way that participating teachers contribute to the design of teaching
activities. This does not mean that teachers should teach the same subject, like in this study. The network meetings may be expanded across different subjects or schools. My study showed that, due to collegiality, teachers were willing to re-examine their beliefs and experiment with a teaching focus they otherwise would not consider. I assume that, when teachers from different schools collaborate, a sense of solidarity can also be created. A good example is the ‘Studiestijgers’-group, a teacher network of the University of Groningen. Within ‘Studiestijgers’, mathematics teachers from different schools work in teams under the guidance of a coach on their own educational and professional development (regarding subject matter and pedagogy). These teachers can be generally regarded as progressive professionals. They may play a leading role in the school regarding professional development.

6.6 Outlook on teachers’ professional development

This study underlines that the introduction of system wide educational reform requires schools to allocate time for school and professional development. Possibly, one of the reasons the ‘Basisvorming’ was not successful, was because teachers said they have had limited opportunity for professional training (Roelofs, Vermeulen & Houtveen, 1998). With respect to the ‘Basisvorming’, teachers indicated that in realizing the core objectives the domains ‘skills’ and ‘statistics’ remained behind, especially when it came to research strategies, processing data with the computer and interpret output (Roelofs et al., 1998). It is important to listen to teachers in their demand for professional development. Although professional development of teachers is seen as one of the essential means to increase the quality and image of education, a survey of teachers in lower secondary education shows that 88 % of the teachers participated in professional development (OECD, 2014), but the time spent is below 10% of the standard year task, which should be devoted to professional development according to collective agreements (Van Veen, Zwart, Meirink & Verloop, 2010). About half of the teachers wishes to spend more time in training activities. The OECD-study also showed that in many countries (including the Netherlands) professional development is often limited to one-day meetings, such as seminars and the like. These meetings, however, have (much) less effect than longer-lasting and more intensive projects, such as gaining a higher qualification or doing research (individually or in collaboration with colleagues). Few teachers participated in these latter types of professional development, while this is, according to the teachers, most effective. Teachers should have the opportunity to experiment and obviously, the school board should support these activities, as cooperation in departments
is more valuable than corridor chats (Onderwijsraad, 2013). Furthermore, in the new Dutch collective agreements 2014-2015, teachers are free to spend their annual budget for professional development, consisting of 5% of their standard year task and 600 euros. The Dutch Ministry of Education, Culture and Science has launched various plans to increase the quality of Dutch teachers. In the report *Actieplan Leerkracht van Nederland* (Ministerie OCW, 2007), the Ministry concluded that the Netherlands is on the brink of a dramatic shortage of good quality teachers. The signal from the report was that educational innovation primarily is a matter for the professional, which is the teacher. In a covenant was established that teachers should receive better compensation, more training opportunities and a greater say in educational innovations. Professional development trajectories as in this study, could be expanded as coach trajectories within schools, where collegial consultation and sharing knowledge and experiences could play a major role, leading to direct impacts in the school. These trajectories should also focus on the more long-term agenda to create attractive work conditions for present and future teachers in schools (Van Veen et al., 2005). The school management can rely on teachers, as teachers are willing to expand their roles because of understandings of and commitment to beliefs of good teaching, collegial expectations, and the moral imperative of teaching to provide the best possible educational opportunities for students (Bartlett, 2001, 2004).

De Vries (2014) states that teachers develop their beliefs about learning and teaching and discover the value of development as an important part of their professional role, when they have abilities to reflect on and analyze their experiences. Another important activity in professional development programs for teachers includes deepening or updating knowledge and refining skills, especially the knowledge and skills developed are those that have been established as effective in achieving valued student outcomes (Timperley, Wilson, Barrar & Fung, 2007). Therefore, it remains important to stay near the subject to be taught and immediate application of training in educational practice. The new examination programs (from 2015) for havo (mathematics A) and vwo (mathematics A and C) contain the subject statistics, which focuses on working with large data sets. That is a big shift compared to the current examination programs. Teachers have to be well prepared for this change. Teaching needs to respond to curriculum changes and the dynamics of society. Schools that want to align to the information society with new teaching methods can facilitate small-scale projects and encourage cooperation and networking so that well-founded examples of professional development occur (SLO, 2011). This lacked during the introduction of the *Basisvorming*. If
teachers had been professionally and pedagogically involved, then the introduction of the Basisvorming would undoubtedly have gone differently.
References


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