Mathematics teachers’ development of practical knowledge
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1 General introduction

The reason to conduct this research was the introduction of the Basisvorming in secondary education in the Netherlands in the 1990s. In this reform mathematics teachers were expected to implement new teaching strategies in the context of a new curriculum. This study focuses on the professional development of mathematics teachers on teaching statistical literacy as part of this new curriculum. I designed and evaluated a professional development trajectory, in which a small group of mathematics teachers from one school collaborated during network meetings on the design of statistical research projects for 7th grade pupils, aged 12-13 years. With this study, I aim to identify how teachers’ development of practical knowledge progressed and which aspects affected this development.

1.1 Mathematics teaching in The Netherlands

In the Netherlands, some major educational reforms in secondary education were implemented during the last 20 years. All these innovations aimed at reducing the dropout, improving the throughput rates of schools, improving the connection to further education and creating more equal educational opportunities for children, in other words to enhance the efficiency and quality of secondary education.

In 1993-1994 a new curriculum for the first three years of secondary education (In Dutch: Basisvorming) has been implemented. All pupils, aged 12-15 years, followed the same subjects – among others, languages, mathematics, history, arts and sciences – and had to achieve the same core objectives. In 2001 a new curriculum for the last two or three years of secondary education (In Dutch: Tweede Fase) was implemented. This part of secondary school allows for differentiation by means of subject clusters that are denoted profiles. The four profiles are: ‘nature and technology’, ‘nature and health’, ‘economy and society, and ‘culture and society’.

In my study, I am particularly interested in the challenges the Basisvorming, the start of secondary education, poses to teacher professionalization. The definition of Basisvorming was formulated by the WRR (1986, p.8) as ‘(…) giving common and general education in intellectual, cultural and social fields, which serves as a basis for further development, for useful functioning as a member of society and a sensible
choice of further education and of a profession’. In order to fully participate in society, all pupils need a common knowledge base. Therefore, the government aimed at achieving minimum goals for all pupils. This meant that all pupils in lower secondary education had to meet a number of established core objectives, which could be worked out differently for the different levels in secondary education (Harskamp & Suhre, 1997). In the Basisvorming this is thought to be realized by emphasis on acquiring basic skills and content that are essential for the functioning in society and indispensable for further development (seeWielemans & Vermeerbergen, 1990, p.59).

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: Toepassing, Vaardigheden, Samenhang) (Harskamp & Suhre, 1997; Van Luyn, 1998). This principle emphasizes that not only knowledge, but also practice and skills, including research skills, are considered important (Inspectie van het Onderwijs, 1999). In addition to the structural changes in secondary education the teaching process should be changed. For example, the TVS-characteristics implied pedagogies like inquiry-based and collaborative learning (Roelofs & Houtveen, 1999).

In lower secondary education in The Netherlands, there are nine core objectives pertaining to mathematics. These core objectives are formulated in general terms. Schools can choose their own curriculum to realize the core objectives taking into account learning characteristics of the pupils from the own school. The core objectives focus on giving pupils an active role in learning math skills and ways of thinking, as they reflect ‘communicate with mathematics’, ‘use mathematics’ and ‘doing mathematics’ (SLO, 2007). This is consistent with the above mentioned emphases of the Basisvorming, as pupils become aware of mathematics in society. The following core objectives of mathematics in the Basisvorming (Ministry of Education, Culture and Science, 2006; SLO, 2007, p.6) play an important role in my study:

1. The pupil learns, alone and in cooperation with others, to recognize mathematics in practical situations and to use mathematics in order to solve problems;
2. The pupil learns to set up a mathematical argument and distinguish from opinions and assertions, and he learns, while respecting other people's ways of thinking, to give and receive criticism;

3. The pupil learns to use informal notations, diagrams, tables, graphs and formulas to get grip on relations between variables;

4. The pupil learns to systematically describe, organize, and visualize data and he learns to critically evaluate data, representations and conclusions.

Core objective 1 does not describe the contents of mathematics, but it indicates what pupils are expected to learn in mathematics and how they should learn. Core objective 1 also includes pupils working in groups. Core objective 2 relates to mathematical argumentation and core objective 3 relates to presenting data in tables or diagrams. Core objective 4 relates to statistics, in particular to the key concepts ‘Data collection’, ‘Draw conclusions’, ‘Research’ and ‘Measures of center’ (SLO, 2007).

The reform plans for secondary education obviously affected the mathematics curriculum. As early as 1986, the then State Secretary Ginjaar-Maas stated that a new mathematics program for lower secondary education had to be developed urgently. The Freudenthal Institute, together with the National Institute for Curriculum Development (SLO), laid the foundation for the renewal of mathematics education in the Basisvorming with the W12-16 project. A number of domains from the old math curriculum were replaced by other subjects, with the emphasis on algebra, geometry, arithmetic, information processing, statistics and ‘Integrated Mathematical Activities’ (In Dutch: Geïntegreerde Wiskundige Activiteiten) (Kok, Meeder, Wijers & Van Dormolen, 1992). The W12-16 project aimed at offering meaningful mathematics to all pupils. In the past, the entire mathematics course aimed at providing pupils a broad basis in mathematical knowledge and mathematical thinking, instead of focusing on the needs and abilities of pupils, taking into account their knowledge and their talent (Kok et al., 1992). The new program related to three areas: society, profession and further education, with the intention to provide students with mathematical knowledge and skills useful not only in later life, but also at the moment of learning the mathematical concepts (Kok et al., 1992; Oud-de Glas & Schuyt, 1989). With the introduction of the Basisvorming, applications got a bigger place in the program at the expense of formal mathematics and algebraic techniques and algorithms (Goffree, Van Hoorn & Zwaneveld, 2000). For mathematics teachers, the new program marked
a new effort because they were faced with new types of assignments for pupils, new classroom activities, teaching of new skills and applying new pedagogies.

Although the core objectives of the W12-16 project were not developed from a specific pedagogical perspective, they clearly reflect the principles of Realistic Mathematics Education (RME) (Kok et al., 1992; Van den Heuvel- Panhuizen & Wijers, 2005). RME was developed in the 1980’s and has widely disseminated in mathematics education in primary and secondary schools. According to Vos (2002, p.31), “RME is characterized by the understanding that mathematics is an integral part of real-life. Thus, mathematics is taught, not for its beauty, but for its applicability”.

So, RME involves applications of mathematics linked to the daily life of the pupil. Students can propose realistic solutions and then discuss these solutions with each other, in order to choose the best solution. Vos (2002) mentioned that the development of Dutch mathematics education went hand in hand with international developments. She noticed that the Dutch curricula wandered through three stages, namely from being subject-centered, to being society-centered, and to finally becoming person-centered (see Marsh & Willis, 1995). This meant moving from stressing pure mathematical theory and techniques to using real-world situations and applied problems. In RME, the mathematical content is embedded in contexts, in order to make mathematics meaningful to students. Teaching becomes therefore more student-centered, which is the last of the phases mentioned by Marsh and Willis (1995).

The integrated mathematical activities are used to develop skills as mentioned in the core objectives of the Basisvorming, such as 'pupils learn to recognize mathematics in practical situations' (see above). In integrated mathematical activities, which are about integration of mathematics with the world around us, pupils gain experience in applying mathematics in realistic situations or in practices from other subjects. For this purpose, heuristic methods are often used, as they can help pupils in targeted search for a solution to a problem (Van Streun, 1989). The teaching methods for these
activities can be very diverse, but options are assignments to individual students, group assignments, homework assignments, projects and presentations (Meeder & Schoemaker, 1992a). The goals of integrated mathematical activities are: (1) pupils get acquainted with mathematics that plays a role in topicality, (2) pupils get acquainted with mathematics that plays a role in conjunction with other subjects, (3) pupils learn to practice the use of their mathematical baggage in real life situations (Meeder & Schoemaker, 1992a).

Statistical research projects, in which pupils perform activities, such as collecting, describing and organizing data, processing data with the computer and interpreting the output, provide such an interface of mathematics and society. In the W12-16 program a module ‘Data and Statistics’ was developed for pupils aged 12-16 years. This topic was included to show pupils, on their own level, how mathematics is used in a society where data and mathematical models play an important role in making decisions. A central place in this module is occupied by graphical representations. Central activities within ‘Data and Statistics’ were (1) to retrieve relevant information from complex graphical representations, (2) statistical modeling, and (3) statistical reasoning (Meeder & Schoemaker, 1992b).

1.2 Statistics education

1.2.1 Statistical literacy

There is no other subfield in mathematics that is so widely applied in our society as statistics. In applied sciences, society and the professional world, statistics is mainly about collecting data and about drawing sensible conclusions from these data. Statistics teaching focuses on learning to reason with statistical concepts and attaching meaning to quantitative information. Many types of statistical arguments combine ideas about data and probability, which result in drawing conclusions (including uncertainty factors) and interpreting statistical results. Such arguments are based on key concepts such as distribution, central value, spread, correlation, uncertainty, coincidence and sampling.

Garfield and Gal (1999) distinguish several objectives in statistics teaching, including the understanding of the research process and mathematical concepts as well as
 mastering skills in collecting and processing data, interpreting and critically assessing results and reasoning on the basis of statistical concepts. These competencies have been denoted as statistical literacy (Schield, 1999; Ben-Zvi & Garfield, 2004). Gal & Garfield (1997, p.3, 5) argued that pupils ‘should understand the nature of and processes involved in a statistical investigation and considerations affecting the design of a plan for data collection’ and that they have to develop interpretive skills and statistical literacy. This means that ‘pupils will need to be able to make sense of published results from studies and surveys reported in the media or in a workplace context. Therefore, students need to learn what is involved in interpreting results from a statistical investigation and to pose critical and reflective questions about arguments that refer to summary statistics or to data reported in the media or in project reports from their classroom peers’.

Gal (2002, p. 2) noted that the most common interpretation of ‘statistical literacy’, as ‘a minimal (perhaps formal) knowledge of basic statistical concepts and procedures’ has expanded with ‘desired beliefs, habits of mind, or attitudes, as well as general awareness and a critical perspective’. To be statistical literate, one must have the ability to read and interpret summary statistics in the everyday media: in graphs, tables, statements and essays (Schield,1999), reasoning and arguing with statistical concepts (Schield, 2004). One should be able to understand statistical concepts and reason at the most basic level (Snell, 1999), and one should also become competent in generating and interpreting statistical data. Pupils should be taught the necessary skills to collect, process and interpret data using the available statistical subject knowledge. They should be able to represent their data with graphs or tables, they should be able to reason with their data and they should be able to reflect on their conclusions and on conclusions from others (see also Garfield & Gal, 1999).

In the Basisvorming, pupils are introduced to descriptive statistics. Apart from the fact that descriptive statistics is used in a wide variety of sciences, it is important to have knowledge of its concepts and methods (Gal & Garfield, 1997). The core objective of the Basisvorming “The pupil learns to systematically describe, organize, and visualize data and he learns to critically evaluate data, representations and conclusions”, includes a contribution to statistical literacy. Performing statistical research can be seen as a part of the above mentioned core objective. Statistical research requires that pupils must collect and analyze data. They may use this
information to process and edit tables, graphs or diagrams and calculate and interpret measures of central tendency and spread to characterize the information. Pupils are expected to use computer programs with which they can process data, and interpret the corresponding output (see also Ministry of Education, Culture and Science, 1998). These learning outcomes correspond with standards of other countries, such as in the US for statistics education for grades 6-8, such as ‘Formulate questions, design studies, and collect data about a characteristic shared by two populations or different characteristics within one population’ and ‘Discuss and understand the correspondence between data sets and their graphical representations’ (CSSU Math frameworks, 2004).

1.2.2 Statistics and the need for inquiry-based teaching

Goals of statistics education in The Netherlands (and in the US as well) have shifted from statistical knowledge and calculation skills towards statistical reasoning or statistical literacy (see Burrill, 1991; NCTM, 1989, 1991, 2000; De Lange, 1987). The research literature strongly indicates that pupils learn statistical research skills and become statistical literate by conducting their own research projects. Moore and McCabe (1998), for example, recommend that pupils must experience the process of data collection and data exploration first-hand. Doerr & English (2003) present a detailed analysis of the thought processes in pupils when making connections between different relations, from which they conclude that pupils are very well able to select, arrange and weigh data. Based on their review of research literature and their own research they emphasize that pupils should conduct their own research projects and collect data in order to experience which statistical methods they need to know and be able to apply. Chance (2002) shares this point of view. According to Wild and Pfannkuch (1999), the ultimate aim of statistical investigation is learning in the context domain of a real problem. They state (p.224) that the usual panacea for “teaching” students to think statistically is, “let them do projects”. With this, they can develop a theoretical structure with which they make sense of experience, to learn from it and transfer insights to others.

As in science education, mathematics education should focus more on inquiry in order to meet the needs of the new mathematics program for the Basisvorming. In the past two decades, organizations such as the National Science Foundation (NSF), the National Research Council (NRC), and the American Association for the
Advancement of Science (AAAS) have made significant commitments to improve science education. One common goal of these efforts is to encourage teachers to use scientific inquiry in their instruction as a means to advance students’ understanding of scientific concepts and procedures (Minner, Levy & Century, 2010). Minner et al. (2010) instructed students via some part of the investigation cycle (question, design, data, conclusion, communication) when engaging them with scientific phenomena, and used pedagogical practices that emphasized to some extent student responsibility for learning and active thinking. In my study, inquiry-based teaching is a pedagogical approach that invites students to explore content by posing, investigating, and answering questions (see National Research Council, 1996). In statistics, inquiry-based teaching is suitable for learning and teaching research skills and statistical literacy. A possible conceptualization of inquiry-based teaching then looks as follows: Pupils will conduct a statistical research project including posing a research question, collecting and ordering data, comparing groups, making connections, drawing conclusions and reporting. They will graphically represent their data with a computer program (for example Excel) and use graphic representations (circle diagram, bar graph, histogram) to formulate conclusions (McClain & Cobb, 2001). This approach promotes the introduction of statistical concepts and stimulates pupils to reason about statistical concepts and their application in various situations (see Tolboom, 2012; Garfield, 2003).

A prerequisite for performing statistical research is following a structured research cycle (Pfannkuch & Rubick, 2002). This investigative cycle “concerns the way one acts and what one thinks about during the course of a statistical investigation” (Wild & Pfannkuch, 1999, p.225). When performing the full statistical investigation cycle (Wild & Pfannkuch, 1999), from Problem to Plan to Data to Analysis to Conclusion and, if necessary, then back to Problem (the PPDAC model of MacKay & Oldford,1994), other elements of statistical literacy are needed than when working through the exercises of a traditional textbook for descriptive statistics. For example, according to Gal & Garfield (1997, p.13), ‘the challenge in assessment of statistical literacy is that it should involve examining not only what pupils can do and how they think when asked to, for example, reflect on a report in the media, but also their tendency or disposition to do so without being cued’. This requires a different, new role of the teacher.
Learning in inquiry mathematics classrooms emphasizes the individual’s sense-making processes as well as the social processes. The teacher plays a central role in establishing the mathematical quality of the classroom environment and in establishing norms for mathematical aspects of students’ activity. Teachers can provide more structure in this learning process (Chance, 2002). One of the teacher’s roles in an inquiry classroom is to facilitate mathematical discussions. At the same time, the teacher acts as a participant who can legitimize certain aspects of the children’s mathematical activity (Yackel & Cobb, 1996). Teachers also need to be aware of the need to allow, even reward, alternative ways of examining and interpreting data (Chance, 2002). Concluding, teachers need to apply other or new guidance skills in order to be consistent with this new way of teaching. For the innovations of the Dutch statistics curriculum in lower secondary education, this means that teachers should acquire novel practical knowledge (see Shulman, 1986; Sowder, 2007). The core objectives of the Basisvorming require pupils to learn and work beyond the textbook. Therefore, mathematics teachers need to learn to leave the method and accept new pedagogies of teaching, like inquiry-based teaching. They have to acquire competencies and novel practical knowledge in order to guide pupils through research assignments or integrated mathematical activities, instead of skipping these assignments in their lessons.

1.3 Implementation of integrated mathematical activities

The integrated mathematical activities can pay attention to the newly mentioned skills in the core objectives of the Basisvorming (see section 1.2). Integrated mathematical activities were included in textbooks and in educational materials for teachers (see also Kok et al., 1992; Harskamp, De Haan & Van Streun, 2000). However, the broad implementation of integrated mathematical activities in Dutch mathematics classrooms did not succeed. The Inspectorate of education (Inspectie van het onderwijs, 1999) reported, about five years after the introduction of the Basisvorming, that the skills to apply the gained knowledge were hardly taught. Two years later this finding was corroborated by Van Streun (2001). He noted that pupils in lower and upper secondary education were not encouraged enough in their thinking, in learning to solve problems or in developing appropriate research skills. There were several causes for this. Firstly, integrated mathematical activities were not executed, due to a perceived lack of time by teachers (see also Witterholt, 2003). Secondly, the relation
between the overarching national reform objectives for secondary education and suitable integrated mathematical activities and research assignments for lower and upper secondary education were not sufficiently clear to teachers (Harskamp, De Haan & Van Streun, 2000). Harskamp et al. (2000) contend that to realize the necessary changes in teaching practice, a schoolwide, collective involvement in analyzing goals and activities, making an inventory of practice and putting in place a more systematic and targeted development of research skills would have been necessary. Thirdly, teachers did not possess the necessary experience and skills to create an inquiry-based classroom, partly because the introduction of appropriate teaching methods was not required by school boards (Harskamp et al., 2000). Mathematics teachers had little experience in the search for suitable research projects (Harskamp et al., 2000). Studies have shown that instruction in mathematics classrooms remained overwhelmingly teacher-centered, with greater emphasis placed on lecturing than on helping students to think critically and apply their knowledge to real-world situations (Taakgroep Vernieuwing Basisvorming, 2003).

In conclusion, any attempt to induce professional development needs to address:

1. Time as a limiting factor;
2. Goals of mathematics education in relation to the school curriculum;
3. Teachers’ abilities to apply novel teaching strategies.

1.4 Teacher professional development

In section 1.2 I mentioned that teachers may need to get acquainted with new pedagogies of teaching to realise the objectives of the Basisvorming. According to Gravemeijer (1995), students are expected to justify their solution strategies, listen to others, try to understand the proposed solution strategies, and if necessary ask for clarification or criticize solutions from others. Gravemeijer (1995) noticed that it is important that the actions of the teacher are consistent with these standards, as clarification and especially criticism are non-standard norms in education. Therefore, teacher professionalization is important. Existing professionalization strategies do not seem to work to equip teachers with constructivist forms of teaching. The OECD TALIS study (OECD, 2009) shows that teacher professional development is generally not meeting the needs of teachers in most countries, for example, in the fields of ‘student assessment practices’, ‘subject knowledge’ and ‘instructional practices’. The
main reason for unfulfilled development (according to teachers) is the conflict with their work schedule, but lack of suitable development opportunities is also a significant factor (OECD, 2009, p.48). One strategy for realizing teacher change, often used in the past, is what Chin and Benne (1969) call the ‘empirical-rational strategy’. This strategy assumes that teachers are expected to implement in their teaching practice what they are being told. Research has revealed that teachers are often characterized as being recalcitrant because they refuse to cooperate, and this impedes the process of teacher change (e.g. Duffy & Roehler, 1986; Fullan, 1985). Increasing attention has been paid to the so-called ‘normative-reeducative strategy’ (Chin & Benne, 1969), which assumes that teacher change must take place as a result of reflection on teaching practice, in which consultation with colleagues is an important element (Gallagher, Goudvis & Pierson, 1988). According to this strategy, the changes take place on the teacher’s own initiative, which is an important difference with the strategies in which changes are imposed by school boards or policy makers. According to Guskey’s (2002) model of teacher change significant change in teachers’ knowledge occurs primarily after teachers have experienced evidence of improvements in student learning. Clarke and Hollingsworth (2002) emphasize that teachers should be actively involved in programmes for professional development and that such programmes must be related to the teaching practice. Little (1993, p.147-148) stresses the same, namely that teachers’ motives and opportunities for professional development begin with working conditions encountered day by day, like the teaching assignments they need for their pupils and the allocation of discretionary time. Teachers’ motivations, incentives, and frustrations come foremost from the immediacy and complexity of the classroom: teachers' responses to the students they teach and the circumstances in which they teach them.

In order to deal with the complexity of work during educational innovations, collaboration between teachers is considered as becoming more important (Brouwer, 2011). However, there is no consensus regarding how to define that concept of collaboration (Brouwer, 2011; Lima, 2001; Little, 1990). Cordingley, Bell, Evans & Firth (2005) and Owen (2003) have refined the understanding of the importance of teacher collaboration for professional learning by highlighting the role of joint work (see also Little, 1990) and the need for intense and sustained involvement with colleagues. According to the Organization for Economic Co-operation and Development (OECD, 2011, p.23), teacher collaboration is on the political agenda.
Teachers work together relatively rarely, but they can do more and they should do more to share their expertise and experiences systematically (see also Kok et al., 1992).

Based on the above mentioned recommendations by Gallagher et al.(1988), Little (1990, 1993), Gravemeijer (1995), Guskey (2002) and Clarke and Hollingsworth (2002), I designed a professional development trajectory in which teachers work together in a network on a statistical teaching design for 7th grade pupils. The trajectory provides a framework for studying teacher change and factors that foster or impede change. A main purpose of such a trajectory is also 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, testing pupils and pupil collaboration, during which they reconsider their own knowledge and skills (see Shulman, 1986). The professional development trajectory in this study is designed according to ideas of ‘joint work’ (see chapter 5; Little, 1990). Other principles of the trajectory in this study are (1) Teacher development can be considered as a long-term process (Fullan, 2001), (2) 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), (3) The trajectory builds on collegiate commitment in order to increase the collective efficacy of the group (Fullan, 2001; Jackson & Bruegmann, 2009). Eventually, the study of this trajectory has to result in (recommendations for) an in-service training for mathematics teachers, when adopting inquiry-based teaching to develop pupils’ statistical literacy.

This dissertation aims to identify crucial aspects of teachers’ development of practical knowledge to implement inquiry-based teaching. Practical knowledge is the knowledge, skills and beliefs teachers need to practice their profession (see Meijer, 1999). In later chapters, I will further elaborate the concept of practical knowledge. In our professional development trajectory, teachers learn new pedagogies, new representations of statistical concepts (see Bakker & Gravemeijer, 2004), design skills and collaboration skills in order to support and guide pupils who perform inquiry-based assignments.
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?

1.5 Design of the study
The implementation of my study took place in the first years (7th, 8th and 9th grades) of lower secondary education in The Netherlands, which also includes the Basisvorming. The pupils were aged 12-15 years. I implemented a professional development trajectory for mathematics teachers of the same school. The mathematics teachers voluntarily signed up for participation in this professional development trajectory. The data collection was spread over a period of two years. In the school year 2006-2007 four mathematics teachers developed a statistical teaching design for 7th grade pupils. They came together during six meetings, which I call network meetings. The network meetings were led by the researcher, who also acted as facilitator. After the teachers developed the teaching design, the design was implemented. After the implementation, the design was evaluated in an evaluative network meeting. One cycle of developing a teaching design, implementing the teaching design 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 now the first design was improved by three mathematics teachers of the same school.

As data sources I used concept maps, semi-structured interviews, transcriptions of network meetings and lesson observations in both years, but the first group yielded so many data that I limited my study to mainly this group. In some cases, I will refer to the second year if this provides relevant additional information.

My study has four methodological characteristics that I will explain below:

1. In my study I seek to determine whether the professional development trajectory contributes to teacher change (Creswell, 2012). The aim of the intervention is not only to determine existing practical knowledge, but also to determine how teachers’ practical knowledge changes during the intervention. An important characteristic of the intervention is, that it takes place in teachers’ natural environment. This means that I use natural settings, network meetings and classroom observations, as sources of data. During network
meetings, for example, I can show how decisions actually are made, rather than how they “should” be made (see Lyle, 2003). According to Lyle (2003), naturalistic studies benefit from the minimal intervention in the natural activity. Lincoln & Guba (1985, p. 120) advice that "If you want people to understand better than they otherwise might, provide them information in the form in which they usually experience it”. The researcher attempts to observe, describe and interpret settings as they are, maintaining what Patton (1990, p. 55) calls an "empathic neutrality".

2. My study may be considered longitudinal, as the professional development trajectory became part of the community of mathematics teachers of the school for two years, although with a varying composition of participants. According to Sztomka (1993), the idea of change apart from time is simply inconceivable. Saldaña (2003) mentions that, during long-term engagement, researchers can focus on how people think, feel, and act from moment to moment to capture in-depth perceptions and meanings, to extract stories for narrative inquiry, and to log rich details for individual biography. Additionally, researchers learn how human actions and participant perspectives change during the course of a study. In order to collect evidence of change, Saldaña (2003) specifies nine months as a minimum length of fieldwork time in educational settings.

3. My study is a case study. According to Creswell (2007, p. 73), this is ‘a qualitative approach in which the investigator explores a bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in depth data collection, involving multiple sources of information (e.g., observations, interviews, documents, reports), and reports a case description and case-based themes’. A case study focuses on the diagnosis or evaluation of a specific situation (Wester & Peters, 2004), which is examined during his natural function (Peters, 1995). My research involves the study of four mathematics teachers while collaborating during network meetings. I observe the teachers in the classroom in order to obtain a detailed description of their functioning in a collaborative setting and during their daily practice. I describe the development of practical knowledge in different, single cases.

4. I will collect qualitative data, because I need a detailed exploration and understanding of teachers’ practical knowledge (Creswell, 2007, 2012). My
goal is not to enumerate frequencies, but to expand and generalize theories about teacher practical knowledge (Yin, 2009). Yin (2011, p.2, 6) articulates: ‘The allure of qualitative research is that it enables you to conduct in-depth studies about a broad array of topics in plain and everyday terms’. I collect converging evidence from different sources, which are often used to indicate teacher change (Meijer, 1999), such as (discussions of) concept maps, semi-structured interviews, lesson observations and voice recordings of network meetings and interviews. The grounded theory approach of Strauss and Corbin (1990, 1998) provides a framework to systematically develop categories from these qualitative data. These multiple sources of evidence need to converge in a triangulating fashion (Yin, 2009). The role of triangulation is of great importance, as this methodological technique pertains to the goal of seeking at least three ways of verifying or corroborating a particular event, description, or fact being reported by a study. Such corroboration serves as a way of strengthening the validity of a study (Yin, 2011, p.81).

1.6 Overview of the following chapters
In order to answer the research question of this dissertation, four empirical studies were conducted and a number of sub questions were formulated and answered. Chapters 2 to 5 contain the four empirical studies. These studies can be seen as follow-up studies, as the following study builds on the previous one. In short, the chosen path of the professional development trajectory in this study is: Clarifying teachers’ problems with supervising a prescribed research assignment in the classroom (study 1); Revealing teachers’ concerns regarding the implementation of a jointly developed statistical teaching design (study 2); An in-depth study on the development of teachers’ practical knowledge by means of applying cycles of change from the ICMTPG model of teacher change (study 3); Gaining insight in how teachers learn to teach inquiry-based pedagogies in statistics during network meetings by means of discourse analysis (study 4). The set of findings from the four studies enables me to answer the main question of this thesis. The different chapters are briefly discussed below.
Chapter 1

Chapter 2 (study 1) is based on a study that investigates how pupils developed research skills in the field of statistics in the 9th grade of secondary education. To this end, pupils carried out research, going through an investigative cycle. By means of learner reports, pupils reported about what they have learned about performing statistical research. It is examined whether a definition and operationalization of statistical research skills can take place and whether the statistical teaching design would fit into a learning process for students where they can acquire research skills. I have used this study to clarify learning goals for pupils and teachers, and to map problems of teachers if they supervise statistical research assignments.

Chapter 3 (study 2) is a case study and focuses on teachers’ professional change, when designing and conducting a strategy for inquiry-based student work in the field of statistical research. This study discusses the opportunities for using concept maps as a source of information for describing changes in teachers’ practical knowledge, especially when combined with interviews. This study also reveals teachers’ concerns regarding the feasibility of the design in the classroom and the problems teachers encounter in its implementation.

Chapter 4 (study 3) focuses more in-depth on different phases of the development of practical knowledge of one participating mathematics teacher, who was challenged to redesign her lessons during network meetings with colleagues. I aimed at identifying the events that contribute to the development of her practical knowledge. By applying cycles of change from the Interconnected Model of Teacher Professional Growth (Clarke & Hollingsworth, 2002), I described the professional development of this teacher. Concept maps, discussion of concept maps and subsequent interviews served as sources of information. Discourse during network meetings and lessons observations revealed other aspects of her practical knowledge.

Chapter 5 (study 4) focuses on the teacher collaboration in the network. I examined transcripts of network meetings, from which I show how decisions were made about a teaching design on statistics for 7th grade pupils and its subsequent implementation, which roles teachers take during network meetings, how they reach consensus during network meetings and which aspects of the network meetings promote teachers’ development.

Chapter 6 includes the conclusions and discussion, reflections on the study, implications and recommendations, consequences of the study for teacher change, and suggestions for further research.
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Chapter 1


