Science teachers' meaning-making of teaching practice, collaboration and professional development

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PhD - Dissertation

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Abstract

The aims of the research presented in the thesis are three-fold: 1) To gain an insight into challenges and needs related to Danish science teachers professional development (PD), 2) to understand Danish science teachers' meaning-making when involved in PD designed according to criteria from international research and 3) a research methodological perspective: to adapt, and discuss the use of a specific tool for analysis and representation of the teachers' meaning-making.
A mixed method approach is taken: The empirical research includes a cohort-survey of graduating science teachers repeated in their 2nd year in practice, and two case studies, where one examines the meaning-making of teachers from a science team collaboratively inquiring into video and other artifacts from local classrooms, the other the meaning-making of a group of 4th year student teachers involved in collaborative video inquiries. Two of those are followed until their 2nd year in practice. Findings across papers point to an activity-orientation towards science teaching being widespread among the Danish science teachers. They focus on the students, but on their activities and engagement, not their learning. Furthermore a lack of confidence in having sufficient subject matter knowledge to teach science is widespread. There are significant variations between teachers with various science specializations, but nearly a third of the cohort teachers do not teach science in their 2nd year in practice among other things due to lack of confidence. The case-studies provide examples where science teachers' develop a growing confidence, and begin to focus on students' learning by manipulating *both* science ideas and equipment. The teachers involved in artifact-mediated interactions refer to gaining insight into students' conceptual understanding by purposely experimenting in practice and by sharing their experiences. Scrutiny related to concrete incidents shared with peers seems to be a driving force in their awareness of a need to develop own teaching and in relation to agency looking forward, but confidence and agency also seems to be supported by new tools, theoretical lenses and ideas for transcending practices from the external domain. Finally it is discussed how analysis and representation using an adapted meaning-making model supported an insight into these complex interplays.

Dansk resume

Målet med ph.d.-afhandlingen er at opnå indsigt i udfordringer og muligheder relateret til danske naturfagslæreres professionelle udvikling, og udvide forståelsen af naturfagslæreres konstruktion af forståelse og fortolkning af erfaring (meaning-making), når de involveres i professionelle udviklings-aktiviteter, der følger anbefalinger fra international forskning. Projektet indebærer desuden et forskning-metodologisk perspektiv; en model til at analysere og repræsentere lærerenes 'meaning-making' er blevet udviklet og afprøvet. Data inkluderer en spørgeskema undersøgelse med deltagelse af en kohorte af dimitterende lærere med naturfaglige linjefag, gentaget i deres andet år i praksis, og desuden indgår to case studier. Den ene case-undersøgelse følger lærere fra et lokalt naturfagsteam, faciliteret i at indsamle og diskutere video og andre artefakter fra den lokale naturfagsundervisning. I den anden undersøgelse deltager en gruppe af lærerstuderende med naturfaglige linjefag; de deltog ligeledes i kollaborative video-undersøgelser, for dem i forbindelse med deres fjerde års praktik. To af disse lærerstuderendes følges indtil deres andet år i praksis. Resultater på tværs af de fire artikler peger på, at en aktivitetsbaseret forståelse af naturfags-undervisning er meget udbredt blandt danske lærere. De sætter i deres refleksioner fokus på elevernes engagement, og på at eleverne har hands-on, men ikke så ofte på det naturfag eleverne kan/skal lære gennem aktiviteterne. Desuden peges på læreres lave tiltro til egen naturfaglige forståelse, der påvirker deres forventning til at kunne håndtere opgaven som naturfagslærer, og næsten 1/3 af kohorte-lærerne underviser ikke i naturfag på andet år i praksis. Her er der dog signifikante variationer mellem lærere med de forskellige naturfaglige linjefag. Case-undersøgelserne eksemplificerer, hvordan lærere involveret i artefakt medierede interaktioner udvikler tiltro til egen kompetence, og fornyet fokus på elevernes begrebsudvikling gennem både hands-on og minds-on naturfag. Fælles granskning af konkrete episoder ser ud til at være en drivende kraft i erkendelsen af et behov for udvikling af egen naturfagsundervisning, men fortsat forandring fremadrettet ser også ud til at understøttes af nye værktøjer og forskningsbaserede tilgange præsenteret via udviklingsaktiviteterne.

Contents

List of papers 8
1. Introduction 9
1.1 Background and research interest 9
1.2 Research aim 12
1.3 Research questions 12
1.3.1 Overarching research questions 12
1.3.2 Research questions: background study 13
1.3.3 Research questions for the two case studies 14
1.3.4 Research question: follow-up study 15
1.4 The case study and cross section mix 15
1.5 Organization of the dissertation 17
2. Philosophical foundation 19
2.1 Pragmatism 20
2.2 Sociocultural theories 24
3. Theoretical background 29
3.1 Supporting science teachers' learning 29
3.1.1 Artifacts from practice – video for fostering teachers' reflections 33
3.2 Meaning-making as a conceptualization 40
3.3 The interconnected model of teachers' professional growth 45
3.4 The meaning-making model 50
3.4.1 Personal domain 55
3.4.2 Domain of consequence 61
3.4.3 External domain 63
3.4.4 Domain of practice 66
3.4.5 Domain of collaboration 68
3.5 Danish Science Teachers 71
4. Methodology 75
4.1 Mixed method design 75
4.1.1 Mixed method design and the research for the present thesis 76
4.2 Methods 77
4.2.1 The cohort survey 78
4.2.2 Semi-structured interviews 78
4.2.3 Other qualitative data 79
4.3 Data-analysis 79
4.3.1 The meaning-making model as an analytical tool 80
4.3.2 Data-analysis and the mixed methods design 82
4.4 Quality assurance 83
4.4.1 The questionnaires 83
4.4.2 The qualitative research: Pragmatic and communicative validity 84
4.4.3 Triangulation 86
4.4.4 Participant researcher 86
5. Findings 89

5.1 Paper I - A cohort of novice Danish science teachers: Background in science and argumentation about science teaching 89
5.2 Paper II - Science teachers' meaning-making when involved in a school-based professional development project 92
5.3 Paper III - Pre-service teachers' meaning-making when collaboratively analyzing video from school practice for the bachelor project at college 96
5.4 Paper IV - Science teachers' construction of understanding and interpretation of experiences in the first practice 100
6. Overall discussion 107
6.1 Challenges and needs 107
6.1.1 Orientation towards science teaching and learning 108
6.1.2 Confidence: variations between science teachers and how confidence might be supported 111
6.1.3 Availability of collegial support 115
6.1.4 Main findings 116
6.2 Danish science teachers' meaning-making of teaching practice and collaborative inquiries 117
6.2.1 Support during PD experiences 118
6.2.2 Being challenged – and making meaning 122
6.2.3 Main findings 126
6.3 The meaning-making model and the use of it 127
6.3.1 Domain of collaboration as part of the meaning-making model 127
6.3.2 The teachers' utterances as the unit of analysis 129
6.3.3 Main findings 131
7. Implications 133
8. References 137

Appendix 1 -Paper I
Appendix 2 - Paper II
Appendix 3 - Paper III
Appendix 4 - Paper IV
Appendix 5 - Codebooks
Appendix 6 - List of publications

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Aarhus, June, 2012

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List of papers

Paper I

A cohort of novice Danish science teachers: Background in science and argumentation about science teaching.
Nielsen, B.L. in *NorDiNa, 7(2), 2011, pp. 202-218*

Paper II

Science teachers' meaning-making when involved in a school-based professional development project.
Nielsen, B.L., in *Journal of Science Teacher Education,* DOI: 10.1007/s10972-012-9300-5

Paper III

Pre-service teachers' meaning-making when collaboratively analyzing video from school practice for the bachelor projects at college.
Nielsen, B.L. *submitted to Journal of Teacher Education*

Paper IV

Naturfagslæreres konstruktion af forståelse og fortolkning af erfaringer i den første praksis (Science teachers' construction of understanding and interpretation of experiences in the first practice).
Nielsen, B.L. in *MONA 2012*(2)

1. Introduction

1.1 Background and research interest

The past decade has witnessed a growing consensus among practitioners, in research and at the policy level that the approach to teaching science needs to be reconsidered, and science teachers are seen as the key to accomplishing this task (Osborne, Simon and Collings, 2003; Rocard, 2007). Concerns have been raised at an international level about a need for qualifying both pre-service education of science teachers and in-service professional development, and research has identified at least two highly important interrelated points: that teacher development needs to be seen as a continuum from pre-service teacher education through to in-service teachers' professional learning, and that student teachers and teachers in-service need to acquire competencies for continuing learning from their experiences in the science classrooms (Feinam-Nemser, 2001; Hiebert, Morris, Berk, Jansen, 2007).

But despite such insight, the actuality of teacher development is internationally emphasized to be quite different, often the reality is a lack of connection between subject matter and pedagogical courses, and a lack of coherence:

> "The typical pre-service program is a collection of unrelated courses and (..) professional development consists of discrete and disconnected events" (Feinam-Nemser, 2001, p.1049).

The need for qualifying science teaching and for science specific teacher development across the continuum is also acknowledged at the policy level in the Danish context. Concerns have been raised both before and after recent Danish reforms aimed to strengthen pre-service teacher education about the education of too few science teachers for primary and lower secondary school, and about the science qualifications of those that are educated (Andersen, 2008; Følgegruppen for ny læreruddannelse, 2012). Based on this suggestions have been made to invest in in-service support of science teachers as a first step to develop 'high quality science teaching' (Følgegruppen for ny læreruddannelse, 2012).

However there is *not* a coherent local knowledge base related to science specific teacher development. Some of the reasons might be that Danish teachers for primary and lower secondary school traditionally have been educated in smaller institutions spread all over the country. More recently the teacher education institutes have merged with other educations to become university colleges (UC), but still not classified as research institutions. Opposite to the widespread international traditions of disconnected courses teacher education at the UC's in Denmark is organized as integrated four-year-programs during which the student teachers work with pedagogy, school subjects and internships. However the tradition have been referred to as focusing on the generalist perspective in education to be a teacher, more than on particular subjects such as science (Andersen, 2008; Følgegruppen for ny læreruddannelse, 2012).
It is based on these local traditions possible that Danish UC-educated science teachers' background and approach to science teaching might differ from that of the university educated science specialists studied by much of the international research.
So when starting research for this thesis it was first important to realize that:
We know there is a need for science specific teacher development in Denmark, but we know very little about the precise challenges and needs.

Internationally much research has focused on how to best support (science) teachers' learning. In brief the findings from these studies have indicated that teachers' professional developmental activities gain from being school-based, long term, content focused and from incorporating inquiries into practice (e.g., Ostermeier, Prenzel, and Duit, 2010; Desimone, 2009; Roth, 2007). It appears that some of the most powerful teacher learning experiences can be based on experiences from the teachers' own classrooms (Putman and Borko, 2000), and it seems that artifacts from practice like classroom videos can be important mediating tools in teachers' collaborative analysis of classroom practice (Sherin and Han 2004).
So there is empirical evidence to suggest a consensus on a core set of features related to supporting teachers' professional learning that might serve as a starting

point for future studies of professional development to allow these to build on each other and refine and expand the knowledge base (Desimone, 2009).
But - there is still a huge gap from research to adaption/implementation when it comes to the mentioned core set of features, apparently internationally, and certainly also in the Danish context. Danish teachers' in-service professional development is typically short out of school courses detached from practice.
This leads to the second area for consideration:
We know very little about how these consensus criteria can be adapted to a Danish context - how and if they are experienced as meaningful and whether approaches such as collaborative inquiries using artifacts from practice can support Danish science teachers professionally.

This was first 1) a systemic perspective calling for more knowledge about challenges and needs related to Danish science teachers' professional development, and then 2) a teacher-perspective raising the question of how Danish science teachers might feel supported and make sense of professional development. The third and last area of concern relates to the complicated issue of *inquiring* into the latter issue.
It is acknowledged internationally that it is hard to establish a causal relationship between teachers' informal and intentional learning activities, the way they think about teaching and learning, and the way they practice in the classroom (Pring, 2010; Cochran-Smith and Zeichner, 2005; Loucks-Horsley and Matsumoto, 1999). Analyzing and representing teachers' learning experiences is quite complicated, and approaches used in former research differ a lot. Some research has focused on 'rating' teachers' learning compared to various standards, the results of which can then be represented in graphs and tables. Other researchers have argued to see teachers as active agents in their own learning, not just someone something is being done to, using rich qualitative ways to illustrate individual teachers' sense-making and/or their perceived outcomes from specific interventions for example as narratives and quotes from interviews.
The second area of concern outlined above implies that the focus taken in this thesis is closest to the latter - namely a perspective looking into teachers'

meaning-making[1]: their construction of understanding and interpretation of experiences from the science classroom, from collegial interactions and when involved in professional development activities, but *research tools to analyze and represent teachers' meaning-making in qualitatively rich, but still potentially comparable ways grew to be needed during the research.*

1.2 Research aim

The research aims are aligned to these three areas under consideration:
1) To gain more background knowledge about Danish UC-educated science teachers: their ideas about the teaching and students' learning of science, their needs related to being a science teacher, and challenges and possibilities related to their continual learning informally in their everyday work and during intentional learning activities.
2) To examine the character of Danish science teachers' meaning-making during intentional learning activities designed according to the mentioned consensus criteria: Building on what is known from international research about teachers' professional development and examining adaptation for participants who are Danish UC-educated teachers with science specializations.
And finally - an additional aim that developed during the study:
3) To develop research-tools that can be used to analyze, represent, visualize and support interpretation of science teachers' meaning-making, and potentially - looking forward - also to guide design of, and research into, teachers' professional development.

1.3 Research questions

1.3.1 Overarching research questions

The overarching research questions are:

1) What kind of challenges and needs related to Danish UC-educated teachers' continuing development as science teachers can be identified?

[1] The construct of meaning-making and the philosophical and theoretical background it rests on will be further discussed in chapter 2 and 3 below

2) What characterizes Danish science teachers' meaning-making when involved in facilitated collaborative inquiries using artifacts from practice?
3) How can Danish science teachers' meaning-making be represented?

The nature of these aims and research questions prompted from the beginning an approach using a variety of theoretical and methodological lenses and perspectives, so to say focusing the magnifier on science teachers in various contexts and at various stages of the continuum. Details of the research design and methodology will be discussed later in the thesis, these initial remarks just to clarify that the range of research questions, that I will outline now, guiding the research presented in the four papers, are meant to be answered by mixing cross section surveys and case studies. Some participants have contributed to the empirical research for the thesis repeatedly over time - and by so also rendering possible a longitudinal perspective.
The combination of cross sections and case studies is illustrated in fig. 1 below the research questions for the respective sub-studies.

1.3.2 Research questions: background study

The first paper (paper I) sets out to define the Danish case with respect to continuing professional development by examining the UC-educated teachers' background and approach to being a science teacher.
The research for this paper is - together with the research for paper IV – intended to provide an answer to the first overarching research question.
This sub-study is focused on the reflections of a cohort of UC educated science teachers just about to complete their final year of pre-service teacher education and take up their first teaching appointment (see timeline in fig 1).
The decision to make the first cross-section survey just before the science teachers cross the border into practice follows the idea of teacher education being a continuum stretching from pre-service education to in-service professional development –but I will emphasize that the focus of this thesis is not pre-service education *per se*.
The study is guided by the three questions:

1) What characterizes new Danish UC trained science teachers' science background?
2) How do new Danish UC trained science teachers reflect on themselves as science teachers?
3) How do new Danish UC trained science teachers reflect on science teaching?

Paper IV follows up on the teachers from the cohort in their second year in practice, but first the research questions for the two case studies.

1.3.3 Research questions for the two case studies

The two case studies provide the empirical background needed to address the second overarching research question outlined above and - together with paper IV – they also contribute to answer the third overarching research question.

The second paper (paper II) reports a study of a team of in-service science teachers at a local school. The team included both novices and more experienced staff members. Over a year the team was facilitated in inquiring into (videotaped) practice from local classrooms - an intervention designed according to the consensus principles mentioned previously: *content focus*, *active learning*, *coherence*, *duration* and *collective participation* (Desimone, 2009).
Three questions guided this first case study:
1) How do individual teachers reflect on a collaborative project in a science team using artifacts from practice to focus on students' thinking and learning in science?

a) What outcomes do they identify?
b) To which aspects of the project do they refer?

2) What links do the teachers make between a) and b) and what insight into their meaning-making do these provide?
3) What ideas about teaching and learning of science do the teachers express and how might these influence their meaning-making?

The third paper (paper III) follows a group of pre-service teachers during their last year of teacher education (see fig. 1). During a week of facilitated workshops the student teachers collaboratively analyze video-based artifacts from their individual school practices, like the science team from paper II. Their perspective is that these artifacts can also be used in their final bachelor project. The decision to include this study of student teachers on the cusp of leaving education and beginning practice fits with the argument outlined in relation to Paper I.
The following questions guided this second case study:

1) *Do the students teachers' interpretation of their classroom experiences change after being involved in the process of collaboratively analyzing video artifacts for their individual bachelor projects, and if so, how?*
2) *What do the student teachers themselves emphasize as outcomes from the collaborative video-analysis?*
3) *What further insight into their meaning-making is gained when looking into critical moments in workshop-dialogue illuminating issues raised by the student teachers (RQ 1 and 2)?*

1.3.4 Research question: follow-up study

The last paper (paper IV), including science teachers now in their second year of practice, *both* teachers from the cohort (paper I) and two of the teachers from paper III (see fig. 1), is guided by the questions:
1) What kind of experiences and learning situations from practice do novice science teachers emphasize?
2) What challenges and possibilities for continuing learning in practice can be identified based on this?

1.4 The case study and cross section mix

Fig. 1 illustrates how the four sub-studies fit together referring to a continuum from the fourth and last year of pre-service teacher education into practice as a science teacher. The two case studies shown to the left in fig. 1 involve an

intervention relevant for the second overarching research question. In both cases the participating teachers were followed over a year. The cross section surveys, illustrated to the right in fig. 1, follow the same cohort of science teachers from just before passing the border to practice until their second year as teachers. In paper IV data from the cohort-survey is mixed with qualitative data following up on teachers from one of the case studies at the same stage of the continuum.

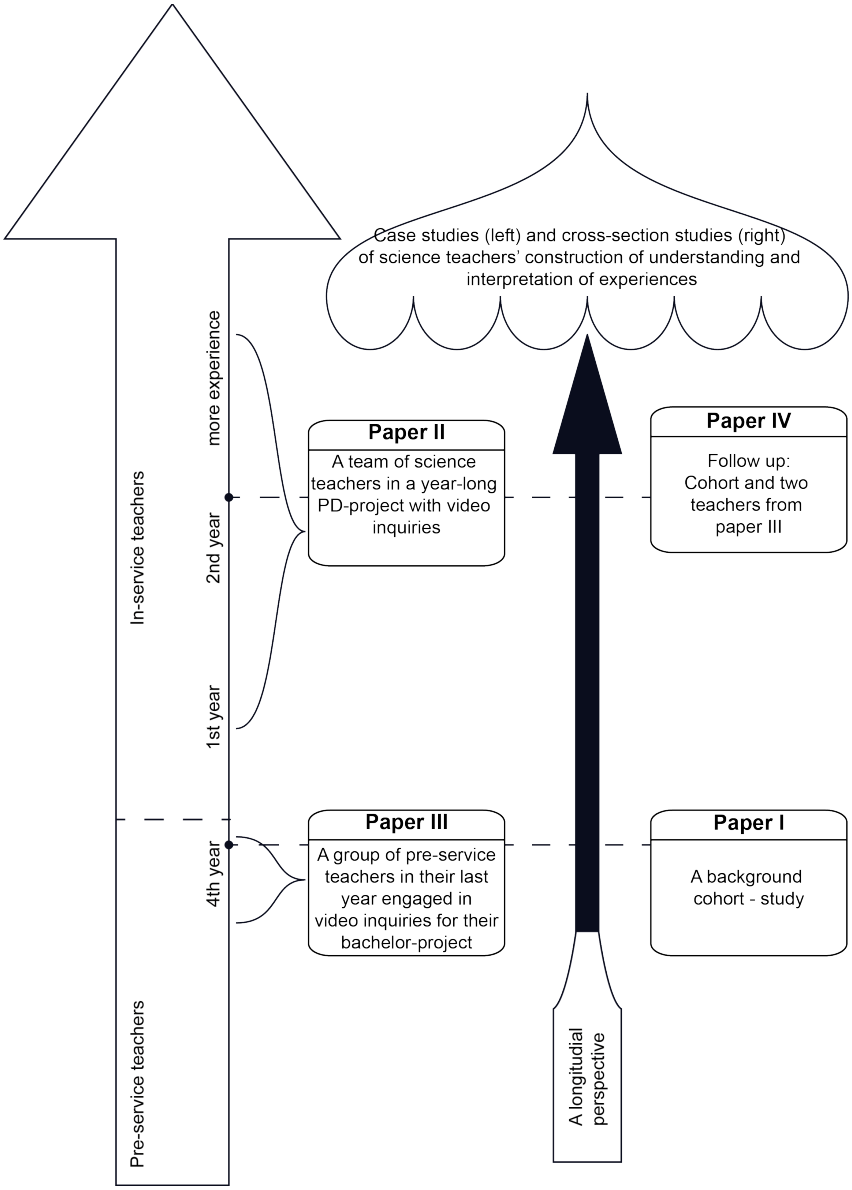

Fig 1: The case study and cross section mix

1.5 Organization of the dissertation

The dissertation now continues with an outline of the philosophical foundation of the empirical research (chapter 2). After this an elaboration of the theoretical background concerning science teachers' professional learning, the construct of meaning-making, how to support science teachers' professional development, and how to inquire into their meaning-making (chapter 3). In all four individual papers the emphasis is on the empirical part of the research, and due to this - and the typical journal format - less space is given over to the theoretical background, which is therefore prioritized in this first part of the thesis.

Chapter 4 focuses on methodology and includes an outline of the design of the research and methods. A more detailed methodology is provided in each of the individual papers, so this chapter is relatively short. Chapter 5 presents the findings as a summary from each paper, and the last chapters consist of discussion, implications and perspectives guided by the overarching research questions, and looking across the set of studies.

Chapters 2-7 were written *after* the papers, and I have decided to make this explicit in the language I use, and the way in which I refer forward to particular points made in the papers. With this in mind I recommend reading the papers found in Appendix 1-4 before chapters 2 to 7.
Starting with the full philosophical and theoretical background (chapter 2 and 3) might however be preferred by some readers.

2. Philosophical foundation

The theoretical framework underpinning this thesis covers two different, but heavily interconnected epistemological branches namely 1) science teachers learning and what we know about how to support it and 2) how to inquire into science teachers' learning, i.e. their meaning-making of professional development experiences. In spite of some consensus related to how to support (science) teachers' learning, as argued in the rationale above, both branches are quite complex and have been heavily discussed in research and developmental literature. It is first of all important to bear in mind that there is not a similar body of research-based evidence related to teaching as a profession as in fields like medicine, while the nature of the field is quite different:

> "*Human beings, and the social life in which they interact, are not the sort of things where there can be simple causal relationships between specific interventions and subsequent behaviors, and this affects the possibility for cumulative knowledge*" (Pring, 2010, p.5).

Therefore a notable feature of the whole field of educational research is the great variety and many different positions and ideological disputes (Pring, 2010). This stresses the need to begin the thesis with the philosophical considerations related to the choices taken in focusing the theoretical background and the decisions about design and methodology, and when discussing and interpreting the findings. Both the choices when conceptualizing a problem and approaches used in its solutions and the validation of conclusions are according to Pring (2010) related to central problems in philosophy. By calling this section 'philosophical foundation' and not for example 'research paradigm' is already exhibiting choice as the selection implies a preference for a skeptical approach to the clear-cut dichotomies that are so often referenced in educational research (e.g. Guba and Lincoln, 2005).

2.1 Pragmatism

The practical and applied philosophy of pragmatism underpins the theoretical and research approaches and the facilitation of teachers' learning used in this thesis. Charles Sanders Peirce was the first to create a formulation of pragmatism and I will return to him below, but to begin I will consider the influential work of John Dewey. Dewey applied pragmatic principles both in developing his philosophy and to the practice of educating not teachers, but children. I will however discuss implications of Dewey's ideas in relation to how to support - and frame an inquiry into - teachers' learning.

Dewey questioned the dualism between theory and practice, and between thinking and doing. From his perspective we cannot discuss knowledge as learned, remembered and believed without including the learners' ability to successfully apply it (Dewey, 1916), and likewise intelligent action in practice arises according to Dewey from systematic theory-informed reflection (Pring, 2010; Dewey, 1938). Dewey described reflective thinking as a state of doubt, hesitation and perplexity and also an act of searching and inquiring to find a way to resolve these doubts (Dewey, 1938). He saw the process of reflection as an active one whereby knowledge is created through experience. Enrichment of experience and intelligent action based on reflection are key concepts both in his pedagogical philosophy, and in his own initiatives to support school students' active involvement in problem-solving.

According to Dewey the quality of learning may be improved if the experience helps the learner to make sense of things, to grab a clearer and more fruitful way of conceiving problems and their possible solutions, and if it leads the learner towards asking further questions and opening further lines of inquiry (Dewey, 1938). Experiences are so to say worthwhile educationally if they support the learner to adapt successfully to new situations and to identify and deal with problems as they arise. Dewey talks about both the *longitudinal* and the *lateral* aspects of an experience (Dewey (1938): The endeavor must be to support the

learner in giving each present experience a worthwhile meaning in itself, but the 'end' must also be seen as the means for yet further thinking (Pring, 2010).

Dewey's ideas about enrichment of experience and intelligent action based on reflection have been very influential also in discussion about education of professionals like teachers (e.g. Rodgers, 2002), and the basic epistemological thinking from Dewey, his focus on both longitudinal and lateral aspects of an experience and his understanding of reflection, has guided both the attempts to facilitate teachers' professional learning, and the analysis of it reported in this thesis. In relation to supporting teachers' learning Dewey's thinking, as elaborated by Rodgers (2002), has guided the approach applied to facilitate teachers' inquiries into their students' learning (the studies reported in papers II and III). In relation to analysis both reflection and new enactment are seen as potential mediating factors in the meaning-making model adapted from Clarke and Hollingsworth's interconnected model of professional growth (Clarke and Hollingsworth, 2002) and used in papers II, II and IV. The model is elaborated on in chapter 3 below.
(Dewey's) pragmatism furthermore guides the research approach seen from a research design perspective. An important point is that the dichotomy between a set of incompatible paradigms and methodologies, i.e. qualitative and qualitative research designs, is challenged in pragmatist philosophy ("false dualism": Dewey, 1916). The widespread tendency for such dichotomy is for example illustrated in the last decades' discussions about a claimed dominance of positivism and post-positivism in some educational research, and the disputes about anti-realism in postmodern movements influencing other branches of educational research.
As stated by Pring (2010) - and Dewey - this opposition is mistaken:

> "The opposition (not the distinction) between quantitative and qualitative research is mistaken. The naïve realism attributed to those who espouse the more quantitative methodology is not justified (..) social constructions are constantly reconstructed as new experiences force us to reshape how we understand things. Hence the need for that interpretive and hermeneutic tradition in which we seek to understand the world from the

> perspective of the participants (...*but*) there are features of what it is to be a person which enable generalizations to be made and 'quantities' to be added or subtracted" (Pring, 2010, p.56)

As a consequence of the philosophical foundation in pragmatism the implicit or explicit avocation of the incompatibility thesis indicated in some literature about research paradigms (e.g. Guba and Lincoln, 2005) will not be mirrored in this thesis. The empirical research will draw on 'mixed methods' (e.g. Johnson and Onwuegbuzie, 2004) in its consideration of the primary research questions. Mixing qualitative and quantitative methods however accentuates, as indicated in the quote from Pring (2010), the importance of a *distinction* between research methodologies, and a careful consideration of the kind of claims that can be made based on various data and methodologies - the foundation of "truth" and knowledge (Guba and Lincoln, 2005). Further consideration about this can be found in the methodology section below, for example in table 1 (section 4).

Besides questioning of a dualism between theory and practice, and between thinking and doing, the pragmatist philosophy also disputes the thinking of an isolated individual facing the world. Keywords in the pragmatist alternative are actions and collectivity (Joas, 1993).
Charles Sanders Peirce was the first to present pragmatism as a principle of inquiry and account of meaning in the 1870's (Peirce, 1878/1992). Referring to notions of clarity from Descartes Peirce states that we, to have a full understanding of 'a concept', must supplement familiarity with it in day-to-day encounters, and a definition of it, with considerations of what *practical bearings* we conceive the object of our conception to have (Peirce, 1878/1992). In his philosophy Peirce challenges Descartes' lonely acting ego and exchanges it with social interactions between human beings trying to cope with challenges they meet when acting (Joas, 1993).
Dewey also disputes 'the ego acting alone' as espoused by the contemporaneous behavioral psychology movement. He challenges the thinking of law-like causal relations between environmental stimuli and the organism's reactions: 'external

stimulus leading to inner processing and then to action' and turns this upside down when claiming that *it is the action that determines which stimuli that are perceived as important in a given context* (Joas, 1993).
George Herbert Mead, who is often mentioned with William James, Charles Sanders Peirce, and John Dewey as significant figures in American pragmatism, likewise was early to consider the development of the self through communication in his philosophical theories. The inter-subjectivity is in the heart of Mead's theories about action (Joas 1993). To understand the individual we must according to Mead understand the group.

The insight from Dewey, that actions can influence which inputs are perceived as important, and the linkage of account of meaning to practical bearings and social encounters from Peirce and Mead, is mirrored in the use of a 'Domain of consequence' and a 'Domain of collaboration' in the meaning-making model adapted in this thesis. The domain of consequence represents what the teacher perceives as salient and important when for example trying new methods in practice, also based on former research indicating that a (facilitated) change in practice and the teacher's subsequent appreciation of the effect of his change may be needed before a change in basic beliefs occurs (Guskey, 1986; Clarke and Hollingsworth, 2002).

So - to sum up - the foundation of this thesis is the pragmatic philosophy, which challenges both the naïve realism attached by Guba and Lincoln (2005) to the positivist ontology, and the total relativism where this is attached to the constructivist ontology (e.g. Guba and Lincoln, 2005, p.195). Furthermore both the understanding of reflection as linked to enactment, of learning as (partly) social, and of issues teachers find salient being potentially important in their meaning-making have basic roots in pragmatism.
But the discussion initiated about individual contra-social learning have also been a part of contemporary European and Russian educational philosophy. The next section about socio-cultural theories – and social constructivism - must be seen in the light of this, albeit filtered through the lens of Pring who wrote:

"Beware of 'isms' – and the distinctions which arise from their rigid application" (2005, p.89). I will not go into details with social constructivism as a paradigmatic position, but exemplify and discuss how the thesis is inspired by the social constructivist epistemology and sociocultural theories.

2.2 Sociocultural theories

Constructivism as an ontological and epistemological understanding has a long tradition in western philosophy referring back to ancient Greece, while *educational constructivism* has its origins in the work of Jean Piaget (Philips, 2000).

Constructivism as an educational theory has in particular been emphasized in the last 50-100 years as a break with behaviorism (e.g. Piaget, 1964), analogous to Dewey's opposition to this psychology referred to above. There are at least two fundamental positions in the literature on educational constructivism: 'individual'- the Piaget tradition- and 'social constructivism' (Phillips, 2000).

Piaget's cognitive constructivism is basically based on learning seen as the individual's active process of assimilation or accommodation, while social constructivism refers to learning through interactions within a social and cultural context: learners *appropriate* understanding through social encounters (Hodson and Hodson, 1998). Besides this distinction between how people learn, the two positions also differ fundamentally in relation to *what it is to learn* – if it is to establish logical rational patterns of thought (the Piaget tradition) or if learning is about appropriation of the culture.

Social (educational) constructivism often refers to the inheritance from Lev Vygotsky's cultural historical tradition established in Russia in the early 1930s. Vygotsky saw development as beginning at the social level, when individuals were inducted into the cultural resources of a society, and he saw the individual's internalization as inextricably linked with the cultural tools of language and speech (Hodson and Hodson, 1998).

James Wertsch (1991) early suggested using the term *sociocultural* to cover this area of social constructivist/cultural historical theories and among other influential researchers using the same terminology has been Gordon Wells (1999) writing about dialogic inquiry.

Wertsch (1991; 1995) problematizes, with explicit reference back to pragmatism (Mead and Dewey), to Jean Piaget's cognitive constructivism and to the Russians Vygotsky and Bakhtin that research often is based on the assumption that it is possible, and even desirable, to study the individual in isolation, he states that: "it is difficult if not meaningless to isolate various aspects of mental processes for separate analysis" (Wertsch, 1991, p.14). He proceeds to argue that actions are *mediated* and cannot be separated from the milieu in which they are carried out - mental functioning and sociocultural setting must be understood as dialectically interacting. Based on this he calls out for a coherent sociocultural theory of the human mind grounded in human action, and with both action and interaction as basic analytical categories (Wertsch, 1991; 1995). In his discussions of the role of mediating tools, and the situated and dialogical aspects in the development of understanding, he talks about learning as meaning-making. Mastering something is about being able to use concepts and knowledge in a disciplinary manner, but appropriation also encompasses a sense of owning the knowledge and meaning that is produced. When proposing human action as a unit of analysis he includes also utterances as a form of action, and refers to the motives that shape action (Wertsch, 1995, p.61-62).

Wells (1999) continues the focus from Wertsch when stating that his most central claim is that human action typically employs meditational means such as tools and language, in doing so he specifically underpins the inheritance from Vygotsky and his language-based theory of learning (Wells, 1999). Wells (1999, p.126) refers to a dialogical model of reasoning as central in human learning: dialogue with different voices constructing shared knowledge and critically assessing the quality of that knowledge – also here with reference to the conceptualizations from Wertsch (1991; 1995).

Through the last decades of research this understanding of a sociocultural epistemology, seeing learning and knowing as *social*, *distributed*, *situated* in a context, and *mediated* by cultural artifacts, has been further established in a range of fields - also in the field of teacher development.

- *Situated* learning basically means that how we learn a particular set of knowledge and skills, and the situation in which we learn, are both fundamental to what is learned (Putman and Borko, 2000). Following from this transfer of learning, de-contextualization and re-contextualization of what is learned, is difficult. This is a process where the learner typically needs support. An example concerning teachers is the process of de-contextualizing and re-contextualizing in practice what is learned during pre-service or in-service education.
- *Social* learning implies that interactions with people in our environment influence what is learned. *But* the literature reveals some variation in perspectives ranging from 1) considerations focused on individuals' learning, but seeing it as framed and influenced by discourse in various communities, i.e. looking for individual teachers' change in knowledge and beliefs and/or teaching practice and in doing so examining potential influences from collaboration (e.g. Meirink, Imants, Meijer, and Verloop, 2010), to 2) defining learning as enculturation in the discourse and practices of a particular community (Wenger, 1998); i.e. looking for changes in patterns of participation in socially organized activities in a group of teachers when looking for learning (van Es, 2009).
- *Distributed* learning means that learning encompasses the individual, other people and various mediating artifacts, both physical and symbolic tools (e.g. Putman and Borko, 2000).

Summing up - learning and knowing as development and reconstruction of meaning through interactions with peers - situated, social and distributed - has its roots in the philosophy of both Vygotsky and pragmatists like Dewey (Putman and Borko, 2000). Account of meaning as a part of reaching understanding and

making ideas clear is mentioned above with reference to pragmatism (Peirce, 1878/1992), but the understanding of meaning-making as it is used in this thesis is philosophically anchored in sociocultural perspectives (e.g. Wertsch 1991; 1995). Teachers' meaning-making will be discussed in the next chapter, but to further exemplify the influence from socio-cultural theories the attempts to support sharing and co-construction of knowledge through facilitating dialogue in a community of science teachers and of student teachers as in the interventions in paper II and III are inspired by sociocultural theories. The same is the data-analysis. First and foremost in focusing on examining *mediating factors* like action (enactment) and reflection, but also in acknowledging co-construction of knowledge. In the basic description of the meaning-making model as an analytical model below the focus is on *individual* teachers' meaning-making - concerning the various way of seeing social learning the position taken is alike the one taken by Meirink et al. (2010), with the individuals as a unit of analysis, but it is individuals operating with meditational means and in collaboration (Wertsch, 1995, p.64), and one of the papers includes specific analysis of workshop dialogue (paper III).
Furthermore the work is founded on sociocultural theories about *school students'* dialogue and exploratory talk in the science classroom by means of the analytical tool used by the student teachers in paper III to analyze their video excerpts. This analytical tool developed in another research context (Andersen and Nielsen, 2011) is inspired by Mortimer and Scott's (2003) research into communication in the science classroom – research explicitly anchored in sociocultural theories.

A first conclusion must be, that the pragmatic and sociocultural epistemological philosophies presented in this section, though physically developed independently of each other, can be seen as weaved together in contemporary research into teachers' learning, as emphasized for example by both Putman and Borko (2000). Philosophically there might be potential conflicts, for example ontologically in the understanding of the nature of knowledge when relativism is attached to constructivist ontology (Guba and Lincoln, 2005, p.195), but I will, as several researchers referred to here (e.g. Wertsch, 1991; 1995; Putman and Borko,

2000; Borko, 2004) not focus on these paradigmatic controversies, but emphasize the research for this thesis as theoretically anchored in both pragmatism and sociocultural theory.

Returning to the initiating question of the nature of teacher learning and how to inquire into it, I will let Jerome Bruner have the last word for now. Bruner was a contemporary of Piaget and Vygotsky and, during his long career, moved from a mainly cognitive understanding to advocating a social constructivist and cultural psychologist philosophy. When talking about how to understand and explain other peoples' minds Bruner refers to approaches from educational research and states that '*meaning making is a central feature of cognition in the symbolic world of culture*' (reference to how teachers learn) and that both interpretation and explanation are necessary to the research process: '*the two are mutually enlightening, but not reducible to each other*': (reference to how to inquiry into teachers' learning) (Bruner, 1996, p.112-13). Bruner's stance against an incompatibility thesis closes the circle in relation to the philosophical underpinning of the use of mixed methods elaborated on in the methodology section, and to meaning-making as a conceptualization and teachers' learning as distributed, situated and mediated by cultural artifacts – both of which will be addressed in more detail in the next chapter.

3. Theoretical background

The theoretical background will in the first sections start from the same two interconnected branches as chapter 2 namely science teachers learning and how to support it and how to inquire into and represent science teachers' meaning-making. This will lead to presenting a meaning-making model, and reviewing research concerning the various domains in this model, in section 3.4. Finally section 3.5 will consider the specific case of Danish science teachers.

3.1 Supporting science teachers' learning

The epistemological understanding of teachers' learning as situated, social in nature, distributed and meditated by tools and artifact is outlined above in chapter 2. In this section I will proceed to review research into science teachers' learning, and how this can be supported through professional development (PD) activities, in particular how teachers can benefit from working with meditational means such as video-based artifacts from practice. In this first section I will use the general term 'learning' – as the respective authors do - and 'meaning-making' as a construct will not be further defined till after these first examples, but when doing so I will include both these concrete examples and the philosophical considerations from above.

The situative perspective focuses attention on how various settings and contexts might give rise to teachers' learning – how their learning experiences are often grounded in classroom experiences either the informal everyday experiences or professional development activities where they use experiences from the classroom (Putman and Borko, 2000). Likewise Edwards (2002) and Borko (2004) explicitly refer to teachers' learning as situated agency, not as something being done to the teachers, but as their ongoing development of the capacity to interpret the affordances of particular situations and change their actions accordingly. This stresses that teachers' learning is both a process of enculturation into the local practice at a given school - coming to understand how to participate in the discourse and practices of a particular community, i.e. a

science team at a given school - and a process of active individual construction of understanding (Borko, 2004).

Bell and Gilbert (1996), researching through many years in the field of science teacher professional development, emphasize this when stating:

> "We support a view of learning in teacher development which considers both the development of the individual's construction of meaning towards the socially agreed to knowledge and the reconstruction and transformation of the culture and the social knowledge itself (..) the interaction of the individual with the social can change both" (Bell and Gilbert, 1996, p.50)

I will as mentioned discuss 'construction of meaning' (meaning-making) as it is used in the present thesis below (3.2), but what about the last part of the quote, how can these partly social learning processes be seen to change the social – the collegial interactions at a school – and at the same time be anchored in the individual teacher's classroom?

Bell and Gilbert (1996) with respect to gradual changes reported by and seen in the practice of teachers participating in their research suggest a model of teacher development with various phases, however stating that it is not a stage model, the phases can be interwoven and jumped over, although they are outlined with a progression (Bell and Gilbert, 1996, p. 16). In this model they refer to a partition between *personal*, *social, and professional development* – personal development is about what the individual teacher feels and thinks, social development is about collaboration, and professional development is conceptualized as changes in classroom practice.

I would personally use another term for the latter as I see professional development (learning) as *both* a change in cognition and practice, but when referring to Bell and Gilbert I will apply their concepts, and though this particular partition can be challenged, the model reveals some interesting perspectives concerning the interplay between personal and social development.

According to Bell and Gilbert (1996) the initial phase in teachers' professional learning consists of personal development: coming to realize that some aspects of own practice are problematic, social development: developing a willingness to discuss own practice with others - and finally - professional development: taking on the role of teacher-as-learner and trying out new activities in the classroom. In the next phase personal development involves coping with restraints like fear of losing control and uncertainty of the demands on own subject matter knowledge. Social development involves teachers coming to see the value of collaboration, trusting colleagues, becoming more ready to share experiences, and to renegotiate and reconstruct shared knowledge - and finally -professional development evidenced by more coherent practice. This phase can trigger more articulated and reflective conceptions of science teaching and the realization of a need to integrate conceptions with practice and reconstruct what it means to be teaching science (conceptions are referred to below in section 3.4.1).
In the final phase in the learning process the teachers might feel more empowered (personal development), they begin to trust that what they are doing can produce the outcomes they desire, and also feel empowered in relation to collegial interactions (social development) leading to them potentially continuing to develop professionally (Bell and Gilbert, 1996). The latter is in many contexts referred to as professional development growing to be sustainable, that changes are maintained after the input from developmental activities stops, or - even better – generative, that the process of change continues.

This way of outlining science teachers' professional learning stress that the development-process consists of multiple dimensions: gradual personal empowerment alongside a development in the patterns of collaboration.
As stated by Wertsch:

> "Action is not carried out either by the individual or by society, although there are individual and societal moments to any action (..) an account of action cannot be derived from the study of mental functioning or sociocultural setting in isolation (but) provides a

> context within which the individual and society are understood as interrelated moments" (Wertsch, 1995, p.60)

Furthermore it is evident from Bell and Gilbert's model that teachers' construction of understanding needs to deal with and to refer to classroom practice – and their students' learning of science (e.g. Fishman, Marx, Best and Tal, 2003) although teacher PD can of course also produce a range of other outcomes for example implementation of new curricula and changes in school culture (Loucks-Horsley and Matsumoto, 1999). Linking teacher learning to student learning can be seen in the 'two-level models' used in the design of professional development activities for teachers (Fishman et al., 2003; Dijk and Kattmann, 2007), for example when teachers' learning is focused on their students' alternative conceptions in science. Research in the field of science education has shown that such conceptions are difficult to change and at the same time have a profound influence on what the students learn (e.g., Driver 1989; Scott, Asoko, and Leach, 2007).

Joyce and Showers (2002) specifically connect an iterative design of teachers' professional development to the challenge of transfer mentioned above (situated learning section 2.2), and to the goal of professional development activities capable of producing sustainable and – maybe - generative change:

> " Teachers and administrators formally studied implementation and used results to inform the next cycle of planning, training, and implementation. In other words staff development did not end until transfer was achieved" (Joyce and Showers, 2002, p.12).

> "Mastery of new skills, especially when they differ substantially from existing skills, is rarely sufficient for implementation in classroom practice. Introducing a new procedure or teaching strategy into an existing repertoire of instructional behaviors generally creates dislocation and discomfort. Yet, considerable practice of new behaviors is required if teachers are not only to become technically proficient with them but also to integrate them sensibly and appropriately with existing behaviors" (Joyce and Showers, 2002, p. 80).

So to sum up from these first examples of research into science teachers PD an iterative design acknowledging personal and social development as interconnected and focused on students' understanding of the science content is emphasized.

The design of the intervention, the school-based PD-project for a team of science teachers, that frames the research reported in paper II, is an example of iterative design on two levels – the classroom level and the program. Teachers in the local science team were facilitated in examining their students' pre-conceptions and alternative conceptions in a range of concrete science areas, with the use of video and other artifacts from practice, and in experimenting in the classroom and refining their teaching: an iterative approach at the classroom level. Likewise the PD workshops were iteratively designed during the year of the study and responded to concerns raised by the teachers in an attempt to best support their ongoing development process. The design of the analytical workshop for student teachers reported in paper III likewise included teachers' inquiries into students' learning by the use of artifacts from practice.

Now I will continue the review to research specifically using video-based artifacts as meditational means in (science) teachers' PD.

3.1.1 Artifacts from practice – video for fostering teachers' reflections

Artifacts from practice can for example be classroom video, students' work, their drawings, writings, etc., and assessment data. They are 'pictures' from concrete classroom events with a focus on students' development of conceptual understanding and their thresholds in this process. The potential of artifacts from practice to be mediating tools in teachers' learning has been the theme in a substantial body of research, in particular with a focus on the potential of using various kinds of classroom-video to foster teacher reflection.

A branch of this research has examined the so-called *video-clubs*, where groups of teachers' meet over a period of time and watch and discuss excerpts of video

from their classrooms (van Es and Sherin, 2002; Sherin and Han, 2004; Sherin 2007; van Es and Sherin, 2008; van Es, 2009).

Sherin and Han (2004) review various kinds of *video-clubs,* or the so-called *video study groups* (Tochon, 1999). Most reported cases involve a teacher educator or researcher who serves as a facilitator, but there are cases where a teacher serves this function. A typical goal is to use the video excerpts for collaborative inquiries: to question and reflect on issues that appear salient to the teachers from the specific sections videotaped, but video-clubs can also have a particular theme or focus (from subject and/or pedagogy) that runs through from the first trials in classrooms to the videotaping of these trials.

Sherin and Han (2004) emphasize the opportunities in engaging teachers in activities where they do not have to respond immediately to the situation as when standing in the classroom situation, and where reflection and fine-grained analysis can be supported by repeated watching of certain interactions. They report results from following four teachers in such a video-club - results that indicate that discourse over time changed from a primary focus on the teacher to increased attention to students' actions and ideas, and that the teachers' analyses of student ideas grew to be increasingly detailed.

In (van Es and Sherin, 2008) changes in teachers' thinking when participating in a video club designed to help them notice and interpret students' mathematical thinking are likewise examined. They, like several other research reports examining video reflection (e.g. Seidel, Stürmer, Blomberg, Kobarg and Schwindt, 2011; Sherin, 2007), draw on the notion of *professional vision* (Goodwin, 1994) that refers to professionals' (i.e. teachers') ability to notice and interpret significant features of a practice (i.e. classroom interactions).

Van Es and Sherin (2008) focus on the challenge for teachers to develop such professional vision and claim that learning to notice, the development of professional vision, consists of three main aspects: 1) identifying what is important in a teaching situation, 2) using what one knows to reason about the situation and 3) making connections between the specific events and broader principles of teaching and learning. They back this claim referring to prior research about teacher reflection as the key to improving teaching, and to

founding their work in the conceptualization of reflection from Dewey, seeing learning to notice as an important dimension within the process of reflection (van Es and Sherin, 2008, p.247). What the teachers notice is examined both through analyzing their dialogues and interviews. The results suggest that there was a development in what the teachers found noteworthy, their level of specificity, and that they followed different paths in developing their observation skills (van Es and Sherin, 2008). All the teachers increased their focus on interpreting students' mathematical thinking and became more detailed in their observations. But how they developed varied from individual to individual and their development was apparently related to their respective knowledge, beliefs and experiences.
Some of the research into video-clubs has also focused on the social development. Van Es (2009) examines the roles of various participants in a video-club based on an explicit definition of teacher learning as shifts in patterns of participation (see various ways of framing social learning, section 2.2 above). The results show how the teachers developed to propose a variety of interpretations of student ideas, building on each other's ideas and advancing the group's conversations by taking on specific roles, while shifting in the way they participated in those roles over time. The members in the video-club seemed to coordinate their participation to accomplish the goals of the group (van Es, 2009).

Other recent studies besides this specific research program on video-clubs have also focused on how video can support the development of a shared language in a team of teachers (e.g. Borko, Jacobs, Eiteljorg and Pittman, 2008; Franke, Kazemi, Shih, Biagetti, and Battey, 2010; Zhang, Lundeberg, Koehler, and Eberhardt, 2011) and how video can help teachers shift the focus towards students' thinking and learning (e.g. Rosaen, Lundeberg, Cooper, Fritzen and Terpstra 2008; Star and Strickland, 2008; Stockero, 2008; Eilam and Poyas, 2006).
The work from Borko et al (2008) presents how they adapted a 'problem solving cycle model' for a professional development program for mathematics teachers in order to frame their support of teachers' analysis of video from their own classes. The participating teachers when looking back on the two-year PD program

reported that watching and analyzing video was the most valuable aspect of this program. In particular they referred to how viewing video from their own classrooms allowed them to identify areas for their own improvement, and how observing their colleagues in action inspired new strategies and helped them better appreciate their students' capacity for mathematical reasoning. Furthermore they realized that they as colleagues all struggled with similar issues. These experiences, which seemed to be meaningful and important to the teachers, motivated them to want to continue to learn - the program succeeded in creating a community in which the members felt confortable learning from video and using what they learned to move forward (Borko et al, 2008).
These examples of how professional development activities, i.e. collaborative video-inquiries, can create outcomes teachers appreciate, and by so doing support their continuing engagement in changing practice is elaborated on in section 3.4.2 below – with particular reference to the so-called domain of consequence in the meaning-making model I will present.

In relation to the focus on students' thinking and learning Rosaen et al (2008) examine whether the way student teachers in school practice reflect on their discussion-based teaching is more complex when using video than if they write down their reflections from memory. They conclude that the participating student teachers made more specific observations of students, and their work with the content in the video-supported reflection than in memorized reflections, where the focus was more on classroom management. Based on this Rosaen et al. (2008) discuss the power of video-based reflection to make student teachers *notice*, *revisit*, and *investigate* how they can facilitate students' discussion of the subject matter.

Star and Strickland (2008) also focus on pre-service teachers. Their rationale starts by problematizing that student teachers in general tend to leave college with poor observation skills. Following this they present their research where they look into video viewing in a method course as a mean to improve the student teachers' ability to be observers of classroom practice (Star and Strickland,

2008). They use the conceptualization 'ability to notice' (professional vision) referred to above. They theorize that inexperienced teachers tend to focus on the teacher rather than the students' actions and ideas, that they are not particularly observant about issues of content, and that they might be good observers of static features of a classroom (equipment used etc.), but not of dynamic features such as the line of discourse and communication between teacher and students (Star and Strickland, 2008).
The findings from pre- and post assessment are profoundly exemplified and discussed. One example illustrates how the student teachers in the post assessment were aware of many issues related to communication: teachers' questions, waiting time etc., not noticed in the pre-assessment. Another example highlighted how the student teachers seemed to become more aware of what to look for in terms of the (mathematical) content, and to notice students' reasoning in more detail (Star and Strickland, 2008).

Through the literature base on video as a tool in teacher reflection another ongoing theme has been the potential of using video from teachers' own and close colleagues' classrooms versus using video staged with an aim to foster teacher reflection on a particular focus areas (e.g. Seidel et al., 2011; Janík and Seidel (eds.), 2009; Brophy (eds), 2004).

Sherin, Linsenmeier and van Es (2009) refer to some evidence indicating that teachers will gain more from watching authentic, realistic classrooms than from watching staged interactions. They proceed to a discussion of characteristics of video-excerpts that are productive for teacher reflection and emphasize three main dimensions: the extent to which a clip provides a window into students' thinking, the depth of thinking shown, and the clarity of the thinking (Sherin et al, 2009).

Seidel et al (2011) focus on the *individual* teacher's reflection (individual interviews) not on the individuals' reflections in the group-context as is the case for most of the projects reviewed above. They use an experimental approach to

investigate teacher learning - conceptualized as knowledge activation and professional vision - when analyzing video from one's own versus others' teaching. The results are not straightforward, but they state that the teachers who reflect on video from their own classroom noticed more 'relevant' components of science teaching and learning (teacher's guidance of students' scientific inquiry etc.), and that they appeared more active and motivated. So even though the involved teachers seemed to be less critical and self-reflective, when commenting on video of their home classrooms, the tentative conclusion is that it makes sense to involve video of one's own teaching in professional development activities (Seidel et al, 2011).

Summing up from the reviewed studies involving teachers in video-clubs etc., teachers seem to benefit from shared reflections on authentic clips from own and colleagues classrooms both in terms of what they notice (student learning) and the way the argue about this (professional vision). Furthermore a development of collaborative patterns has been noticed in some studies.
These promising results inspired the design of the interventions in papers II and III. When designing the workshops for the student teachers (paper III) in particular the issues about challenges in relation to student teachers developing the competences required to notice how their students struggle with the subject matter and awareness of communicative patterns in the classroom (e.g. Star and Strickland, 2008) have been taken into consideration. The dynamic features mentioned by Star and Strickland - the line of discourse and communication between teacher and student - are central elements in the analytical tool applied by the student teachers (Andersen and Nielsen, 2011).
In the studies with video-artifacts reported in papers II and III the video used was authentic clips from the participating teachers' classrooms. Based on the present review there seems to be some consensus regarding the benefit of using video from teachers' own classrooms with in service teachers. When it comes to pre-service teachers there have likewise been discussions surrounding whether they should be asked to reflect on exemplary lessons, ones containing recognizable lessons or if they should reflect on their own efforts from school

practice, and be asked to comment on issues arising from each other's filmed activities. There has been less research on how pre-service teachers can collaboratively analyze video from *their own* school practice compared with the large number of studies on in-service teachers' video clubs (Yerrick, Ross and Molebash, 2005). Some studies describe the successful use of *staged video-cases* to develop student teachers' level of reflection and their ability to ground their analysis in evidence of their students' thinking (e.g. Stockero, 2008). Other research indicates that the reflection process is less engaging if it is vicarious rather than personal for student teachers (Yerrick et al., 2005). Some researchers emphasize, therefore, that the practice of using video with images of expert practice or experts' analysis of teaching episodes created to make experts' tacit knowledge available to novice teachers, do not offer the opportunity for the novices to make their own observations, or analyze and interpret themselves (van Es and Sherin, 2002).
In the present study the in-service teachers worked with video of their own classrooms and therefore it seemed appropriate to use collaborative video analysis of own and peers teaching also with the group of student teachers as well. The participants are pre-service teachers in their 4th and last year of teacher education, and so on the cusp of graduating into practice. It is not to claim that exemplary lessons and staged video cannot be useful in other contexts in pre-service teacher education. The decision relates to the discussion on this thesis' preference to see science teachers' learning as a continuum running from the education received in college through the professional development activities offered while in service - it could be argued that there may be good reasons for making a distinction between novices and experienced teachers rather than pre-service (student teachers) versus in-service (Feinam-Nemser, 2001).

Most of the reviewed studies have examined how, and on what, teachers reflect on when collaboratively discussing video-based artifacts, and how their reflections develop over time compared to some data-based or theoretical 'levels'. This thesis has however set out to focus on teachers' meaning-making: how the collaborative work with video analysis makes sense to them. Based on the

concrete examples of teachers PD mediated by video-based artifacts – and the philosophical consideration from above (section 2) - I will now move closer to this conceptualization.

3.2 Meaning-making as a conceptualization

It is outlined above that research into science teachers' learning is necessarily a very complex enterprise and one where it is seldom possible to establish a simple cause-effect relation between for example new input in a PD project and the integration of such input into practice. This stresses the teachers' agency and intentional actions, their experiences of opportunities for active engagement and their understanding of experiences and own learning, as a focus in research into teachers' learning as stated by Edwards (2001) in an argument for her focus on teachers' meaning-making.

It has also been outlined how research into teachers' learning basically has to look into both their cognition: how they think about science and science teaching, and their actions and reflections situated in the classroom - including how they might read the landscape in the classroom in increasingly informed ways, and how they refer to using available resources and tools.

Furthermore it is argued that pragmatism and sociocultural theory allow a weaving together of mind and actions, individual and group and macro and micro contexts. Account of *meaning* in a semiotic context is referred back to Peirce (Peirce, 1878/1992), but *meaning-making* is basically anchored in sociocultural theories (e.g. Wertsch, 1991) as an individual process of appropriation, but an individual operating with meditational means and with individual and social processes intertwined.

The short definition of meaning-making I have used when initiating the research for this thesis is *the teachers' on-going construction of understanding and interpretation of experience in a particular setting or context*, this must be followed by emphasizing that 'setting' includes the interactions within local learning communities, and that meaning-making includes both reflections and a connection to initiating (new) enactments.

Meaning-making situated in a collegial community as a setting is exemplified by Edwards (2001). She situates teachers' meaning-making in situations where they assist the meaning-making of learners and focuses on teachers' informed responsible agency: their capacities to *interpret the affordances of particular situations* and *change their teaching accordingly* (reflections and enactments) and she states that she sees knowledge building as the individual's capacity to make meanings, to interpret objects and events, *but* also the individual's capacity to use this to inform and interact within the local knowledge communities (Edwards, 2001).

The research into video-supported PD referred to above can also be used as an example to explain the "definition", though the researchers do not themselves use the term meaning-making. The teachers in video-clubs share video-excerpts and - mediated by repeatedly watching these excerpts - they (re-)interpret their students' ideas and their conceptual understanding, and they construct individually and collaboratively an increasingly detailed understanding of students learning (e.g. Sherin and Han, 2004).

Other studies include the development of a shared language and the social development in a local learning community (e.g. Borko et al, 2008; van Es, 2009). A few studies also includes the teachers' new strategies to use in the classroom and how they move forward (Borko et al, 2008), but representing how the teachers' connect their reflections to new enactments is not the focus in many of studies.

The methodological challenges in doing so is further discussed in section 3.4, and so are the challenges of representing an ongoing process, but first I will look into some prior research into science teachers' PD actually using the conceptualization meaning-making (e.g. Nichols, 1997; Ebenezer, 1995). Meaning-making is explicitly used in a number of studies looking into students' dialogue and learning in the science classrooms (e.g. Mortimer and Scott, 2003), but not so many studies where the learners are science teachers. I will however refer to three studies, that all apply the conceptualization of meaning-making. I will look into in particular the connection between methods used to *support*

teachers in their meaning-making, and methods used to *research* into their meaning-making, to bride to the next section, 3.3, focusing on analysis. Teachers' meaning-making can be seen as closely connected to the process of developing professional vision (Goodwin, 1994, above 3.1.1). A representation of a teachers' meaning-making can be hypothesized to produce an insight into the *processes* that might or might not lead to the *product*, their professional vision, but - again - professional vision is a detailed construct when it comes to level and content of teacher reflection, but not explicitly connected to new enactments.

John Loughran, who in a research paper examines elements of reflective practice in teacher education, exactly refers to student teachers' meaning-making as connected to professional ways of seeing and noticing:

> "Encouraging the episode (*from school practice*) to be reconsidered, developed and articulated (..) enhances the meaning-making from the action in the practice setting, and can settle some of the taken-for-granted assumptions about teaching (..) and increase the likelihood that new ways of seeing might emerge" (Loughran 2002, p.37).

He however emphasizes that effective reflective practice involves both 'seeing' and 'action' to enhance the possibility that the student teachers learn through experience, and that these two components interact in a teacher's decision making: that teachers' meaning-making involves their conscious and subconscious/tacit filtering of actions and responses (Loughran, 2002). Furthermore Loughran challenges a common post-practicum approach in pre-service teacher education, where it is the teacher educator who 'puts theory on' the students teachers' experiences. He states that we - in planning developmental activities *and* researching into and evaluating them – have to focus on participants' meaning-making:

> "If the focus is genuinely on the student teacher as learner then it is their ability to analyze and make meaning that matters" (Loughran, 2002, p.38).

Loughran in his own research approach uses anecdotes and assertions, quoted from the student teachers, to exemplify findings and as the background for conclusions related to how reflective practice in teacher education can be important in the development of one's professional knowledge. The study is quite interesting, but how the students teachers reflections might lead them on in (planning) new enactment is not an explicit focus in the presentation of the findings.

The research from Ebenezer (1995) likewise implicitly connects science teachers' meaning-making to their development of professional vision, and furthermore to their collaboration in learning communities. The research is about a particular case, an example of an approach to teacher education, and it is argued, that looking into participating students teachers' meaning-making provides insight into this case (Ebenezer, 1995). This approach to teacher education is about facilitating student teachers' collaborative action research by making them research into their own school students' ideas about concrete science concepts. The main discussion in the paper is related to how this intervention helped the individual teachers to *see* a qualitatively different way of teaching and learning. The method used by Ebenezer to gain an insight into the student teachers' meaning-making of their own science instruction is to analyze interviews with the student teachers and their conversations about the artifacts from their action research.
In the conclusions the involved student teachers' personal frustrations and tensions relating to change, and some institutional constraints at the teacher education institution, are identified as decisive factors in relation to their development of professional competence through the experience with collaborative action research. Furthermore *risk-taking* by the student teachers is concluded as important, and it is questioned if schools and universities actually encourage risk-taking and mistake-making (Ebenezer, 1995, p.103). All these findings are illustrated by excerpts from dialogue and quotes from the student teachers. Those are not in particular focused on new enactments based on the reflections, but this is implicitly a focus when working with action research.

Nichols (1997) also connects science student teachers' meaning-making to the use of various tools and artifacts in teacher education, *and* also uses quotes, anecdotes, drawings etc. from student teachers to back the claims in the paper. She refers to science teachers' meaning-making as socially mediated critical reflection. Though using the term 'a tool-kit' in the title of the paper she warns against a 'fix-it' perspective in teacher education, and emphasizes the importance of introducing student teachers to approaches *they can use to continue to learn from, and enhance, their own practice* (Nichols, 1997, p.81) – new enactments. She discusses a range of tools that can be applied in this process, e.g. portfolio design, journal writing and writing classroom cases, and how those tools can be used by the student teachers not just to learn *specific* strategies for teaching science, but to critically reflect on what constitutes meaningful science learning (Nichols, 1997).

This was a short reference to three examples of research using the conceptualization meaning-making. The approach applied to represent the (student) teachers' meaning-making - including their perceived outcomes from specific interventions - is in all those papers to use narratives, excerpts from dialogues and quotes from interviews. In this way teachers' meaning-making is represented in a qualitatively rich way providing a deep insight into the particular cases, in particular in the science teachers' reflections.
However during the first analysis of the qualitative data collected in the present research a need grew to build on these rich traditions to acknowledge individual teachers' experiences as the key to gaining insight into how best to support and facilitate their professional learning, but also to try and develop (new) ways of representing teachers meaning-making in potentially comparable ways and to aggregate some of the complex information into visual patterns.
The discussion so far indicate at least three challenges: One challenge is how to include both reflections and the new enactments the teachers plan and/or initiate, another is how to include the interconnection between an individual's meaning-making and the intertwined level of social development and a third is

that meaning-making is 'defined' as an ongoing process and how this can be represented.
I will now look into research using the so-called interconnected model to represent teachers' professional learning, i.e. their professional growth.

3.3 The interconnected model of teachers' professional growth

Several researchers working on the professional learning of teachers have developed models that try to capture and interpret the complex interplays and potential mediating aspects related to teachers' learning processes. The interconnected model of teachers' professional growth (Clarke and Hollingsworth, 2002) is based on an understanding of teachers as active learners shaping their professional growth (the conceptualization used by the authors) through reflective participation in their daily work, PD programs etc. (Clarke and Hollingsworth, 2002).
In the rationale for seeking an interconnected model Clarke and Hollingsworth challenge the naïve linear thinking used in design of many PD programs aiming to change teachers' knowledge and beliefs by providing them with information about various teaching approaches, and then expecting a causal chain where this information will lead to changes in the teachers' classroom practice and ultimately to changes in their students' learning outcomes. They refer to Guskey (1986) who claims that the most significant changes in teacher attitudes and beliefs come *after* they begin using a new practice successfully and see changes in student learning, suggesting that a (facilitated) change in practice and the teacher's subsequent appreciation of the effect of his change may be needed before a change in basic beliefs can occur. They however do not prescribe in the model the relation to be as so, but acknowledge it as a possibility.
Based on empirical research from three Australian studies Clarke and Hollingsworth synthesize their interconnected model which suggests that teachers' professional growth occurs through the mediating processes of reflection and enactment connecting four distinct domains (situated in the change environment), namely:

- Domain of practice: professional experimentation for example in the classroom; *something the teacher tries*
- Personal domain: teacher's knowledge, beliefs, and attitudes; *something the teacher knows or thinks*
- Domain of consequence: salient outcomes; *consequences the teacher draws*
- External domain: information, stimulus, and support from external sources; *something the teacher experiences (by help from) outside the school*

Clarke and Hollingsworth emphasize that the external domain is located outside the teacher's personal professional world, which is constituted by the three other domains in combination, encompassing the teacher's professional actions, the inferred consequences of those actions and the knowledge and beliefs that prompted and responded to those actions (Clarke and Hollingsworth, 2002, p.951). Referring to the mechanism whereby change in one of these dimensions can trigger change in another Clarke and Hollingsworth as mentioned propose the two mediating processes: Enactment and reflection. Enactment is a deliberate putting into action of a new idea or a new belief, and reflection is an active persistent and careful consideration (Clarke and Hollingsworth, 2002, p. 254). Enactment leads potentially to change of behavior whereas reflection leads to a potential change of cognition.

In the outline of the interconnected model Clarke and Hollingsworth stress that it is the teacher's interpretive acts, and the change experiences that the teacher considers salient that are important to model - to explain their professional growth. This resembles some of the arguments used above when presenting the conceptualization teachers' meaning-making. Furthermore they exemplify that the model can be used both as an analytical, a predictive and/or an interrogatory tool (Clarke and Hollingsworth, 2002, p.957). Based on this the model is suggested as the starting point to adapt as a tool to analyze and represent science

teachers' meaning-making. But before getting to the adaption of the model used in the present study a little more about how the interconnected model has been used by Clarke and Hollingsworth and by other researchers.

Clarke and Hollingsworth (2002) after presenting the model discuss a range of examples from their empirical research showing how the model was used to identify patterns in teachers' professional growth. They claim that the process by which change can occur can be represented by particular change sequences consisting of two or more domains together with reflective and enactive links connecting them. Where data have demonstrated more lasting change a change sequence is termed a growth network. Based on a range of examples represented like this they conclude that teacher professional growth can occur through a variety of such networks, but that some might be more prevalent than others both across groups of teachers and for the individual teacher, and that it appears that teacher change often involves multiple and cyclic movements between the analytical domains of the teacher's world.
This way of representing change as change sequences and growth networks using the interconnected model has been applied by some other researchers (Van Driel and Beijaard, 2003; Justi and van Driel, 2006; Zwart, Wubbels, Bergen and Bolhuis, 2007; Witterholt, Goedhart, Suhre and Streun, 2012).

Zwart et al. (2007) use the interconnected model to analyze and categorize the learning processes of a group of experienced teachers involved in reciprocal peer coaching, where teachers met in pairs regularly to discuss their efforts to support student learning, and where these pairs of teachers can support each other when experimenting with instructional methods. Based on coding of the teachers' utterances in recorded coaching conferences, interviews, and in digital diaries the results are presented as change sequences.
A range of findings are presented. They conclude that there seems to be various starting points for teacher learning. It can start with either an enactment or reflection, but there is apparently not one answer to whether change in cognition precedes or follows change in teacher practice. Furthermore they state that input

from external domain during formal PD activities is not the only way of initiating a process of teacher learning - they emphasize that they found both patterns including this domain and patterns that did not. In the examples where the support from the external domain is a part of the change networks it is often in a change process that *also* includes activities in the domain of practice and reflections and enactments including the domain of consequence (Zwart et al., 2007).

Van Driel and Beijaard (2003); Justi and van Driel (2006) and Witterholt et al., 2012 introduce Shulman's knowledge categories including Pedagogical Content Knowledge, PCK (Shulman, 1986) into their adaption of the interconnected model, and use this to focus on changes in the personal domain. This particular construct describing teachers' knowledge, beliefs and attitudes – PCK - is further discussed below in section 3.4.1 - here I am looking into the various ways of adapting the interconnected model.

Justi and van Driel (2006) use the original Clarke and Hollingsworth model to analyze and represent teachers' professional knowledge in a particular field of science education namely models and modeling. They specifically base their use of the model on the basic perspective of teachers being actively involved in their own process of knowledge building.

The model is used both as an *analytical* and *interrogatory* tool and as a *predictive* tool related to how to promote teacher development.

The first way of using the model – as an analytical and interrogatory tool - looks into an intervention from external domain - is a course for the development of teachers' professional knowledge related to models and modeling. Examples of results from analyzing questionnaires examining teacher knowledge, combined with interviews etc., are represented as change sequences and growth networks to illustrate the relationships between domains in relation to this particular intervention (Justi and van Driel, 2006). The model is used as a predictive tool to suggest mechanisms by which teacher change might be promoted. One of the conclusions related to this use is that the design of the intervention from external domain that proved advantageous was both connected to the teachers trying

testing it in practice and focused on perspectives *distinct* from those with which the teachers were familiar. Furthermore the benefit of using a design based on a teacher action research project is emphasized (Justi and van Driel, 2006).
Justi and van Driel (2006) conclude that the model was quite helpful in the research process but when looking forward point to the importance of also taking teachers' tacit knowledge and beliefs into consideration when analyzing their professional growth during PD activities.
Van Driel and Beijaard (2003) do not use the model to analyze and represent results from the empirical research projects they refer to, but as a predictive tool to *guide the design* of the professional development activities. This way of adapting the model to design continuing professional development is further elaborated by van Driel (2010). Furthermore collegial interactions are seen as a particular sub-field of interest in the domain of consequence (Van Driel and Beijaard, 2003; van Driel, 2010).
Clarke and Hollingsworth (2002) in the presentation of the model emphasize that - and exemplify how - the school environment can have a significant influence on a teacher's professional growth, and they operate with a change environment surrounding the domains in the original model. One of the factors they situate in the change environment is cooperation with colleagues.
Collegial interactions are however according to the philosophical considerations referred to above in section 2 and a range of other contemporary research projects referred to below in section 3.4.5, assumed to play an important mediating role in the individual teachers' learning. Van Driel and Beijaard (2003) argue about the importance of collegial interactions in relation to the individual teacher's development of PCK and therefore add a collaborative category to their model for teacher learning. The model is consequently adapted with four key elements: external input, teachers' PCK, experimentation in practice and collegial interactions (van Driel and Beijaard, 2003; van Driel, 2010). Based on this the PD activities presented are designed to provide opportunities for teachers to experiment with new teaching approaches in their classrooms, and to reflect on this individually and collectively. The results are presented referring to how the participating science teachers developed PCK in the concrete science areas by the

combined use of individual teaching experiences and group meetings and workshops (van Driel and Beijaard, 2003; van Driel 2010). Looking forward it is recommended to design PD that includes both external input, experimentation in practice and collegial interactions to ensure local ownership and support stimulation of teacher learning through sharing ideas and experiences with colleagues (van Driel, 2010).

The final research relating to the adaptation of the interconnected model that I will shortly refer to is quite new (Witterholt et al., 2012). The research follows a single Mathematics teacher and pursues a chain of events responsible for change in the teacher's PCK. Related to the research is an intervention where lesson planning in a network with colleagues is facilitated by a teacher trainer (Witterholt et al., 2012). In their operationalization of the model they – in contrast to van Driel and Beijaard (2003) - situate these *collegial interactions in the external domain*, i.e. as an external source of stimulus (Witterholt et al., 2012, p. 665). I will not go into details with the specific findings, in stead I will move on to suggesting an adaption of the interconnected model as a meaning-making model, and here I will take into considerations these various ways collegial interactions are suggested to fit into the interconnected model.

3.4 The meaning-making model

The adaption of the interconnected model from van Driel and colleagues and their research results, seen together with how social learning is elaborated on above, and a range of other evidence emphasizing the role of collegial interactions with respect to individual teachers' learning experiences, indicate the importance of focusing on collaboration when analyzing individual teachers' meaning-making. These are just a few quotes about this:

> "Learning in its full complexity involves the creation *and negotiation* of meaning" (Bruner, 1996, p.84).

> "...the individual's construction of meaning towards the socially agreed to knowledge *and* the reconstruction and transformation of (..) the social knowledge" (Bell and Gilbert, 1996, p.50)

The adaption of the interconnected model into a model for teacher learning that includes collegial interactions described above (van Driel and Beijaard, 2003; van Driel, 2010) could however not be applied directly. As it is, it is primarily used as a design tool and therefore does not include a separate domain of consequence. This domain is necessary and important in the present study, where teachers' perceived outcomes is seen as a central part of their meaning-making. Conceptualizing collegial interactions at the school as part of an external domain (Witterholt et al., 2012) is, as I see it, not the solution. There might be arguments for doing so if the individual is the unit of analysis, but I find it crucial to see colleagues as part of what Clarke and Hollingsworth (2002) call the teachers' professional world of practice - and they distinguish the external domain by its location outside this day-to-day world of the teachers (Clarke and Hollingsworth, 2002, p.951). Furthermore seeing interactions with colleagues as part of an external domain can be problematic if looking for interconnections related to how change processes might continue even after professional development activities have stopped. Input and support from external domain in the original Clarke and Hollingsworth model stops at that point – but the possibility for interacting with colleagues does not. Furthermore some of the results referred to above stresses that it can be potentially important to identify which patterns that include input from outside the school (Zwart et al., 2007).

Based on these considerations the interconnected model was adapted for use in analysis and representation in the present study with a new domain of collaboration, and retention of the domain of consequence (Fig. 2).
The domain of collaboration is, using wording analogous to that used above, in italics, about the other domains (section 3.3), referring to *something the teacher experiences mediated by cooperation with colleagues*.

The five separate domains are situated in the change environment (Clarke and Hollingsworth, 2002) and linked by the arrows reflection and enactment to represent how change in one domain influences change in another.

The outline of the model seen in fig. 2 below does not use a particular signature to distinguish the external domain from the others as in the original Clarke and Hollingsworth model (square versus circles). Such clear distinction might however be important in other contexts if adapting the meaning-making model.

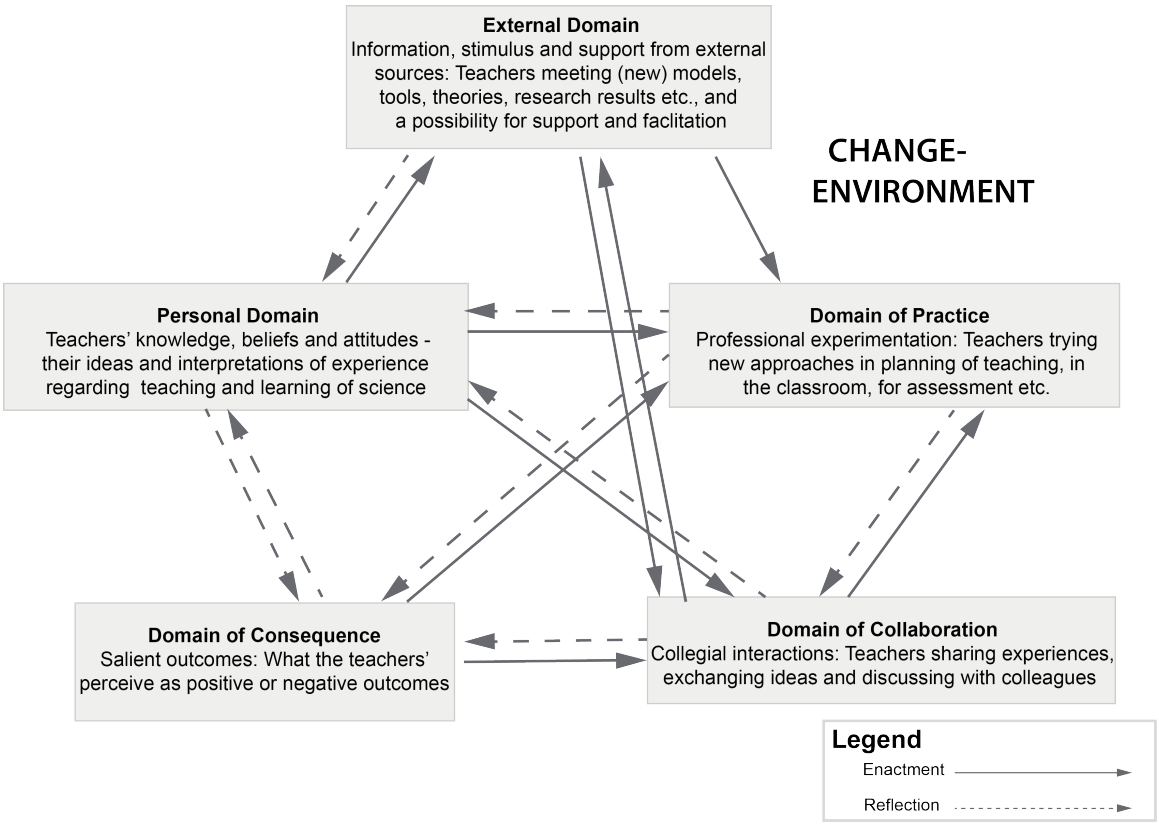

Fig 2. The meaning-making model

The potential bidirectional nature of the mediating factors - including *both* reflection and enactment in the model - is central. As emphasized above visualizing the connection between teachers' reflections and their (planning of) new enactments is important if wanting to represent their meaning-making.

Dewey's work has inspired much contemporary research into teacher development. When looking into what he calls '*reflective thinking'* it, in some of his formulations, encompasses also new enactment, while he, when talking about '*intelligent action based on reflection'*, separates two sub-processes of 'reflective thinking' (section 2.1) as it is done in the interconnected model and in the meaning-making model presented here.
Also in contemporary research ways of defining and conceptualizing teachers' reflection are open to some confusion – and much discussion - in the research community.

> "The value of reflection to the development of teachers has a growing consensus (..) but there is still debate over the way in which reflection is defined" (Ward and McCotter, 2004, p.244)

Donald Schön in a heavily quoted work about practitioners' knowledge maintains, with reference to Dewey, that reflection should also lead the practitioner to new action (Schön, 1983). The construct of teachers' reflective practice has been central in much research and developmental work in the field of pre- and in-service teacher education since the work of Schön (1983). And in later literature he is often referred to as starting the main break with technical-rationality thinking, that suggested that teachers develop just through the 'application of theory' (see the 'theory and practice' discussion below in section 3.4.3). So I will based on the clear separation of reflection and action from Schön maintain the two mediating factors as central in the model, and claim that the two-way mediation - when identified – can illustrate situations of what Dewey (1938) calls the 'quality of experience', that the learner makes sense of an experience and continues towards further lines of inquiry based on this.

Ward and McCotter (2004) quoted above apply a rather straightforward definition of reflection, clearly anchored in Dewey's reflective thinking: "*Deliberate thinking about action with a view to its improvement*". This definition makes the *potential* connection to new enactment clear.

Meaning-making might be expected to be a gradual and interwoven process, where a teacher reflect on experiences and use this to plan and enact something new, mirrored in this definition. To represent teachers' meaning-making it is however important to differ between reflection and enactment.
Oner and Adadan (2011, p. 480) talk about reflection as *re-organization and reconstruction of experience*. This is aligned to the 'definition' of meaning-making as it is used here. When using the meaning-making model in analysis, for description in codebooks etc., where reflection refer to mediation between various domains the functional definition has however been '*persistent and careful consideration*' as used by Clarke and Hollingsworth (2002).
Enactment I will also define referring more or less to Clarke and Hollingsworth (2002) as: "*Deliberate putting into action something new*" and I will like them emphasize that an 'enactment-arrow' is identified in analysis when something leads to change of behavior, whereas a 'reflection-arrow' is identified when something leads to change of cognition – in both cases with 'something' relating to the content of the various domains.

The meaning-making model as outlined in fig. 2 with general phrasings used to describe the five domains could, like the interconnected model, be expected to have a potential as both an analytical, interrogatory and predictive tool. As outlined in the introduction one of the research aims is: "To develop research-tools that can be used to analyze, represent, visualize and support interpretation of science teachers' meaning-making, and potentially - looking forward - also to guide design of, and research into, teachers' professional development".
Potentials in using the meaning-making model as a predictive tool will be a part of the discussion of implications (chapter 7), but as a research tool for this thesis the central issue is the use of the model as an analytical tool and a tool to make representations. This is described in general in the methodology section 4.3.1, and in the papers II, III and IV, and discussed referring to the third overarching research question in chapter 6.
For now I can sum up referring to the three challenges I pin-pointed above when ending section 3.2: The meaning making model includes both reflections and new

enactments. It is focused on an individual's meaning-making, but the intertwined level of social development is included and it indicates meaning-making as a process that can follow various trajectories. In relation to the latter section 4.3.1 includes more considerations about how to represent an ongoing process.

Now I will continue the review of relevant theory and research related to teachers' meaning-making under the headlines from the adapted model.

3.4.1 Personal domain

The personal domain as described by Clarke and Hollingsworth (2002), and in the meaning-making model in fig. 2, is framed as the teacher's *knowledge, beliefs and attitudes*. A full review of research into teachers' knowledge, beliefs and attitudes cannot be accomplished within the scope of this thesis. Instead there will be a more focused consideration of works relating to knowledge and beliefs with respect to teachers' meaning-making and how teachers prompt, interpret and respond to experiences in their professional world of practice, and to experiences initiated from the external domain.

In the adaption of the interconnected model used by van Driel and Beijaard (2003) and Justi and van Driel (2006) teacher knowledge is conceptualized as Pedagogical Content Knowledge (PCK). The construct of PCK is used in their design of professional development activities for teachers and for the analysis of teacher learning in specific fields of science education.
For the past 25 years PCK has been used to identify and discuss teachers' professional knowledge, in particular in the field of science education (e.g. Abell 2007; Berry, Loughran and van Driel, 2008; Nilsson, 2008). PCK was first introduced by Lee Shulman (1986) who raised the question about what kind of knowledge bases were needed for teaching. According to Schulman. PCK was defined as the knowledge required for teaching of a subject, i.e. science, the amalgam of content and pedagogy that is uniquely the province of teachers:

> "The most useful forms of representation, the most powerful analogies, illustrations, examples, explanations and demonstrations" (Shulman, 1986, p.9).

PCK is highly content and context dependent, and the 'PCK-view' on teacher learning with regards their knowledge acquisition is that teachers construct the knowledge that guides their actions in practice alongside their growing experience in teaching a particular content. This means that learning to teach involves integrating and/or transforming different kinds of knowledge *and* importantly, as suggested by Magnusson, Krajcik and Borko (1999), also *beliefs*: pedagogical knowledge and beliefs, subject matter knowledge and beliefs, and knowledge and beliefs about context.
In a recent review of the research using the construct of PCK Sandra Abell stresses the sometimes vague application of PCK in science education research, but still she, like other science education researchers (e.g. Berry, Loughran and van Driel, 2008), emphasizes the huge importance of more research into *subject-specific*, i.e. science-specific, teacher knowledge, and the strengths of continuingly using the construct of PCK in such research (Abell, 2007).
Nilsson (2008) supports this when stating that the concept of PCK in her research has proven to be fruitful as a construct and a model. She refers to PCK as the knowledge a teacher needs to construct and implement *science learning experiences for the students* (Nilsson, 2008). Nilsson stresses that the important focus – instead of arguing about how to define PCK - is to identity and discuss the *processes involved in teachers' development of PCK*; and sums up on PCK as a dynamic knowledge constantly in development along with the teachers' *experiences of planning, conducting and reflecting on science teaching and learning*, and as a type of knowledge transformed from other forms of teacher knowledge (Nilsson, 2008).

PCK is not used as a primary conceptualization in the research for the present thesis, but it is referred to as a generic term related to subject specific teacher competence in papers I and IV. It can however be noticed that PCK seen as a dynamic knowledge, as it is outlined by Nilsson (2008), is consistent with the

emphasis on teachers' meaning-making processes, and *both* enactment and reflection in the meaning-making model. Furthermore Nilsson (2008) places a teacher's focus on the students learning of science in the center of his/her development of PCK, also consistent with the aims of the interventions referred to in the present thesis.

In the general outline of the meaning-making model in fig. 2 three main categories: knowledge, beliefs and attitudes are listed in the personal domain. Evaluating participating teachers' knowledge, for example their subject matter knowledge or pedagogical knowledge, which are elements in the construct of PCK, have not been a part of the empirical research for the thesis, and this is highlighted in the specific outline of the model in the papers. In paper II the personal domain is for example specifically limited to '*teachers' ideas and interpretations of experience concerning teaching and learning science'*. So pursuing teachers' ideas/beliefs is a part of the empirical research, and now I'll look further into theory related to teachers' beliefs, and in particular ideas related to the teaching and learning science.

Arguments have been made – and evidence has been found - that teachers' beliefs may be even more important than knowledge when making decisions in the classroom (e.g. Pajares, 1992). Two teachers may have similar knowledge, but teach in very different ways. A teacher's beliefs seem to form a somewhat tacit, but still decisive conceptual map for instructional decision-making (Pajares, 1992). A simple causal relationship between beliefs and actions in the classroom can however be hard to establish (see Mellado, 1997 below), but the importance of teacher beliefs in relation to their professional decision-making is widely acknowledged, and early in the PCK research beliefs became a central component of PCK (e.g. Magnusson, Krajcik and Borko, 1999).
The influence of beliefs and ideas about a subject is also included in the discussions of teachers' reflections when involved in video-clubs: the research reviewed above (section 3.1.1). It is emphasized how hard it can be to put what you immediately think happened – colored by your beliefs - aside and focus on

alternative interpretations of what might have happened in a given classroom interaction (van Es and Sherin, 2008, p.261).

Pajares (1992) claims that beliefs are the best indicators of the decisions individuals make, however later research, do, as I will exemplify below, challenge the correlation. Pajares sees a somewhat unclear distinction between what are beliefs and what is knowledge in research and pinpoints the more affective components of beliefs – that beliefs seem to operate independently of the cognition associated with knowledge (Pajares, 1992, p.309). Based on his review Pajares categorizes educational beliefs as being for example about the nature of knowledge (epistemological), about students' performance, and about confidence to perform specific tasks: *self-efficacy beliefs* (Bandura, 1982). Pajares continues to state that educational beliefs often will refer to teaching and learning in specific subjects and disciplines (Pajares, 1992, p.316).
I'll elaborate more on self-efficacy below, but first there will be a discussion of the specificity of educational beliefs for science teachers, in particular.

Mellado (1997) relates his discussions of *science* teachers' beliefs to PCK and the subject specificity of this construct, when referring the potential for subject specificity of teacher beliefs. Instead of using the term 'beliefs', he uses the term 'conceptions', but explicates that those two terms are much alike with reference back to Pajares (Mellado, 1997, p.198). Mellado also occasionally uses the term 'ideas' to refer to the thinking about the teaching and learning of science in a broader sense (Mellado, 1997, p.204). In using the label 'conceptions' Mellado refers back to Hewson and Hewson (1989) who define conceptions related to science teaching and learning as:

> "The set of ideas, understandings and interpretations of experience concerning the teacher and teaching, the nature and content of science and the learners and learning which the teacher uses in making decisions about teaching, both in planning and execution" (Hewson and Hewson, 1989, p. 194).

Mellado discusses in his rationale how science teachers are hypothesized to inherit deeply rooted conceptions about science concepts, the nature of science and the way to teach and learn science from their own school experience. He argues that science teachers can be expected to put into practice the kind of science teaching that is compatible with these deeply rooted beliefs. His empirical research looks into the *conceptions* and the *actions* in the classroom of a group of science teachers (Mellado, 1997). The results do not confirm a general correspondence between the participating pre-service science teachers' conceptions about teaching and learning science and their classroom behavior. There are examples of (partial) correspondence, but also of sharp contradictions between conceptions and actions in the classroom (Mellado 1997). So Mellado concludes that the relation between how teachers *think* about teaching and learning science, and the way they *act* in the classroom is quite complex, and that a change in their ideas and actions must be seen as a dynamic process. He therefore suggests supporting pre-service science teachers in analyzing their own classroom teaching in an iterative and meta-reflective process, where they can grow to be aware of these conceptions (Mellado 1997).

Levitt (2002) focuses on *elementary* science teachers and their beliefs regarding the teaching and learning of science. She reports that teachers in many PD programs revert to old practices when the program ends – there is no sustainability – so teachers' beliefs must also according to Levitt be identified during PD to be directly addressed. Levitt goes on to note elementary teachers may be convinced of the value of hands-on-activities, without always being able to develop science content from these exercises - they may not even be aware of what science students are supposed to learn from the activities (Levitt, 2002). Her results show that elementary teachers typically have student-centered beliefs and that they value students' active engagement and their hands-on activities. She states that these results represent a move away from research emphasizing the challenge of science teachers' focus on dispensing facts. This discrepancy is further pursued below in section 3.4.4.

I will use Abell (2007) to sum up on these various strands of research. She states that there seems to be a broad consensus that teachers' ideas about teaching and learning science (or whatever term) are an important parameter in their construction of understanding as professionals. That is science teachers' beliefs influence their cognition and their practice in the classroom although that relation is complex since beliefs can change over time and with context (Abell, 2007). Overall this is a rather messy construct, with the labels mentioned here, as well as the label '*orientations* towards science teaching' being used to cover almost overlapping constructs (Abell, 2007, p.1124).

I'll end this section with reference to a quite new study (Lumpe, Czerniak, Haney and Beltyukova, 2012). Lumpe et al. implicitly maintain the science specificity in their research approach as they are looking into the relationship between *science* teachers' beliefs, their participation in professional development, and their students' concurrent achievement, but they 'return to' using the term beliefs and to refer to the more generic constructs as Pajares (1992), instead of the specific relation to planning science teaching etc. as in the above definition of conceptions from Hewson and Hewson (1987). Lumpe et al. emphasize - and examine with specific instruments - two categories of beliefs: *capability beliefs* and *context beliefs* (Bandura, 1982; 1997).
Capability beliefs are beliefs about one's ability or skill to meet a particular goal – referring to both *self-efficacy*, i.e. the teachers' beliefs in own capacity to effectively teach science, and a related construct *outcome expectancy*: judgment of the likely consequences their performances will produce, i.e. students' learning of science (Lumpe et al., 2012, p.156). Context beliefs refer to the teachers' confidence in relation to the change environment. The empirical research presented in the paper involved 450 elementary science teachers participating in a large professional development project following similar research based recommendations as the ones outlined above in the rationale for the research in the present thesis. The approaches used in the PD furthermore encompassed identifying and clarifying teachers' beliefs prior to and during the PD activities and by so doing to positively impact them, including supporting the teachers' self

efficacy through mastery experiences (Lumpe et al., 2012). Their results show several background variables to be predictive of the teachers' beliefs, but most importantly they found that the teachers' self efficacy related to teaching science positively developed through long-term intense PD.

Science teachers' ideas about teaching and learning science are in this thesis, as in the reviewed research, seen as a crucial component to gain an insight into their meaning-making as professionals. The plurality of terms that Abell (2007) pin-pointed are seen as a reflection of the multifaceted and complex nature of such ideas, and therefore the thesis does not try to impose a common terminology. In paper I the terms used in the research cited - beliefs, orientations or conceptions – are used. In paper II the data-based analysis of the teachers' utterances about teaching and learning science led to the decision to use the broader label 'ideas' in the analysis and discussion of findings, but here specific terms such as conceptions are also used when referring directly to that part of the research base.
Additionally, the participating teachers beliefs about their own competence as science teachers – indicating their efficacy beliefs - are referred to in the discussion in the papers, and in the overall discussion in section 6 below. In section 3.5 the international research including teachers' self-efficacy mentioned here is supplemented with a reference to previous Danish research looking into novice Danish science teachers' self-efficacy.

The next section will consider in more detail the domain of consequence, where teacher beliefs seem to play an important role in relation to the consequences teachers draw for example from their PD experiences.

3.4.2 Domain of consequence

The domain of consequence was suggested as part of the interconnected model by Clarke and Hollingsworth (2002) with reference back to Guskey (1986) who claimed that significant changes in beliefs are only likely to take place after

changes in student learning outcomes are experienced first hand by the teachers: A (facilitated) change in practice and the teacher's subsequent appreciation of the effect of his change might be the first step in changing deeply rooted beliefs. So the domain of consequence is basically about what the teacher does or does not appreciate. In the outline of the meaning-making model (fig. 2 above) I suggest that the outcomes teachers experience are salient in relation to domain of collaboration are also an important issue in their meaning-making. This is not directly based on the research base, and for now is a hypothesis. What I will refer to is research looking into consequences teachers draw from practice.

Guskey (1986) refers to several pieces of empirical evidence including an example where a large group of teachers participated in in-service training on the use of mastery learning procedures with school students. Teachers who used the new procedures and saw improvement in their students' learning reacted positively, expressed increased personal responsibility for their students' learning, and continued developing this way of teaching, while the teachers who did not notice any influence on the students when trying some of the new procedures, abandoned the new and unfamiliar practice (Guskey, 1986).
Clarke and Hollingsworth (2002) name these inferred consequences teachers make as 'salient outcomes', acknowledging that teachers value and consequently attend to different things. In their empirical founding of 'The interconnected Model' there are several examples of how changes in a teacher's perception of salient outcomes influence new enactments, and thereby over time potentially gradual changes in beliefs. One example is about a mathematics teacher who participated in a PD program focused on the use of student group work, investigative projects and assessment techniques. First he expressed no need for modifying his teaching practices, but when he tried investigative group work he was pleased with the outcome, namely that his students took more responsibility for their own learning. Thereby he came to continue to experiment with these methods and techniques even after the input and support from external domain stopped (Clarke and Hollingsworth, 2002, p.953).

Fishman et al. (2003) also stress how students' performance influence teachers' knowledge and beliefs mediated through enactment: teachers intuitively look to their students for feedback about new or refined approaches. They talk about this as a *feedback loop* (Fishman et al, 2003, p.646), and the same terminology is used by Lumpe et al. (2012, p.155).
Likewise some of the newest research on teachers' use of video focuses on the influence of video-analysis on such a gradual process of teacher change (Tripp and Rich, 2012). They report that the teachers perceived video-analysis to be beneficial in a process of implementing change in the classroom, and refer to the process of change as consisting of four steps: 1) Recognize the need to change, 2) Subsequent discussion with peers: brainstorming ideas for change 3) Implement ideas and 4) Evaluate changes implemented. As steps in a professional development process this is described in more detail above referring to Bell and Gilbert, 2006 (section 3.1), but in relation to the domain of consequence their conclusions - that participation in the collaborative video reflections seem to have *influenced the teachers' desires to change their teaching* (Tripp and Rich, 2012, p. 738) - are of particular interest. The fact that the teachers felt accountable to the group apparently supported this intrinsic desire to change (Tripp and Rich, 2012, p. 739). Tripp and Rich use these results to suggest that more focus should be placed on such intrinsically driven elements in teachers' change processes. This contrasts with the majority of the literature which sees teacher improvement as mainly extrinsically driven.

So – to sum up: intrinsic drive seems to be necessary for change, but extrinsic input might be necessary for change that transcends tradition to be initiated.

3.4.3 External domain

The external domain refers to sources of information and stimuli coming from outside the teacher's personal professional world. Often this domain represents activities during *formal* learning activities in pre-service and in-service teacher education, for example input and facilitation in a professional development

project as in paper II. The input during the PD described in paper II is represented as coming from an external domain even though the activities are *physically* situated at the teachers' school; colleagues at the school are however considered part of an individual teacher's personal world (the collaborative domain). External domain might also represent *informal* learning affordances. In relation to PD activities for in-service teachers there is, as outlined in the rationale in the introduction, rather much consensus that in-service teachers' PD gains from being school based, long term, content focused and from incorporating inquiries into practice (e.g. Ostermeier et al., 2010; Desimone, 2009; Roth, 2007; Hiebert et al., 2002; Joyce and Showers, 2002; Garet, Porter, Desimone, Birman, and Yoon, 2001). This has been formulated as a set of core features of effective professional development: *content focus*, *active learning*, *coherence*, *duration* and *collective participation* (Desimone, 2009). These consensus criteria are supported by much research into PD for teachers, both rich and detailed case studies and large-scale studies, and are also based on synthesized research designed to establish some of the hard links between teachers' participation in developmental activities, their initiation of new teaching approaches, and students' learning (Joyce and Showers, 2002; Hattie, 2009):

> Not just anything called staff development will generate increased student learning. But some kinds of professional development can produce substantial gains (..) these build learning communities (..) use the knowledge base to shape initiatives while studying (..) instruction and student response on a formative basis" (Joyce and Showers, 2002, p.1)

When it comes to research related to *pre-service* teacher education you cannot talk about the same consensus, few definitive statements about the effects of different models for pre-service teacher education can be made based on research (Cochran-Smith and Zeichner, 2005). Features that constitute successful teacher education programs have however been synthesized in research (e.g. Darling-Hammond, 2006). Two of seven features are relevant for the present research, where design of pre-service teacher education per se is not the theme, but where

student teachers' collaborative video-inquiries are included. Those two are 1) explicit strategies to help student teachers confront their deep-seated beliefs about teaching and learning, and 2) the possibility for extended practice inquiries closely related to the courses at the college (Darling-Hammond, 2006).
The latter, the focus on opportunities for STs to collaboratively inquire into and problem solve concrete classroom experiences, is recognized in a range of reform programs (e.g. Darling-Hammond, Hammerness, Grossman, Rust and Shulman, 2005; Darling-Hammond and Sykes, 1999). The need for student teachers to develop competencies to learn from classroom practice is seen as important in contemporary reforms of pre-service teacher education throughout the world (e.g. Korthagen, Loughran and Russell, 2006).

Calderhead (1988) and Ball and Cohen (1999) were among the first to call for a more inquiry oriented teacher education arguing that teachers need to learn how to investigate what students do and think – and to learn how they can use this to inform and improve teaching. Such emphasis on facilitating pre-service teachers in using practice as a site for inquiry and situating professional discussions during teacher education in concrete tasks or artifacts of practice is also the background for the various research reviewed above using video-inquiries in pre-service teacher education as well as in in-service PD (3.1.1).
Darling-Hammond (2006) emphasizes that an important element of inquiring into practice is to be able to use theory that can help make sense of the phenomena experienced and observed. Opportunities to connect practice to expert knowledge must according to Darling-Hammond consequently be built into learning experiences for pre-service science teachers. She emphasizes that an application of theory into practice-model of teacher education has proven to be ineffective in relation to understanding the way teachers grow.

The complicated interplay between theory and practice during teacher education and PD has been the theme in long lasting discussions (e.g. Calderhead, 1988; Korthagen, 2008). Calderhead (1988) argues that the relationship between theory and practice has to be continuously interactive and that student teachers

need to develop a repertoire of metacognitive skills to continuously evolve in the experimental process of learning in the classroom. Korthagen (2008) supplements this when stating that what is helpful for STs in the process of solving problems in the classroom is what he calls 'small principles t-theory'. 'Generalized abstractions' - T-theory - needs to be connected to sufficient practical experiences in which the theory is consciously used. Various iterative models for tasks where theory can be connected to student teachers' problem-solving processes have been suggested, for example the so-called ALACT model (Korthagen, 2008; Korthagen, Loughran and Russell, 2006).

In the present thesis a formal assignment: the bachelor project, where student teachers inquire into practice frames the research reported in paper III, and here T-theory versus t-theory is included in the analysis and discussion of the results.

The potential mediating arrow in the meaning-making model representing facilitated inquiries into practice in pre-service teacher education, or facilitated trials in the classroom in in-service teachers' PD, is an enactment-arrow from external domain into domain of practice. Clarke and Hollingsworth use this arrow when a teacher enacts in his classroom a new form of pedagogical practice modeled from an in-service session (Clarke and Hollingsworth, 2002, p. 953). Now I will move on to the domain of practice and further discuss 'such enactments': science teaching in the classroom.

3.4.4 Domain of practice

The importance of linking science teachers' professional development to new enactment, based on the teachers' evaluation of consequences in relation to students' learning of concrete science subject matter in concrete classroom settings, has been discussed above. When initiating PD, and/or analyzing teachers' experiences from PD, involving inquiries in local classrooms the question of what constitutes 'good science teaching' becomes critical. So a need for a more normative referent is essential in the present section.

Aligned to the sociocultural understanding of learning, good teaching depends significantly on contextual nuances and variables. But, based on research in science education and the students' learning in general you can - parallel to the consensus criteria for best supporting teachers' learning - argue that there *are* some known criteria.
Hattie (2009) synthesizes the knowledge from the research base into his suggestion of the notion of *visible learning and visible teaching*. The latter refers to the consensus criteria for teachers' PD mentioned above, including teachers experimenting and learning from practice. But Hattie specifically connects this to visible learning by emphasizing the importance of the teacher *seeing learning through students' eyes* (Hattie, 2009).

> "Teachers need to be aware of what each and every student is thinking and knowing, to construct meaning and meaningful experiences in light of this knowledge and have proficient knowledge and understanding of their content to provide meaningful and appropriate feedback" (Hattie, 2009, p.238)

Visible learning is outlined as students partly seeing themselves as their own teachers framed by the teacher involving students in discussion of the intended learning outcomes, and providing feed-back related to these intended learning outcomes focused on what the student already understands, misunderstands and constructs: Where am I going, how am I going, where to next (Hattie, 2009). Hattie states that there is a need to identify and then eliminate misconceptions for all students and refers among other subjects to science, i.e. the research mentioned above about students' alternative conceptions in science (section 3.1).

Related to science specific recommendations for good teaching, contemporary policy papers, based on an extensive review of the research base, identify the main challenge for reforming science in school as the widespread use of a transmission approach; it is challenged that science teachers often take a 'chalk and talk' approach instead of a more inquiry-oriented approach as is recommended in many reform curricula (Rocard et al., 2007; Osborne and

Dillon, 2008). But focusing only on the challenge of a transmission approach might, as I argue in the theoretical background to paper I, simplify the issue. Studies involving in particular elementary (primary) science teachers have highlighted a somewhat opposite problem, a purely activity-driven approach with students spending a lot of time doing science, but little time thinking, talking, posing questions, or constructing explanations, with the goal of making science interesting, enjoyable and fun, but without much focus on what is learned (Abell and McDonald, 2006, Levitt, 2002). In relation to this challenge it is important to state, that a contemporary understanding of inquiry-based science education specifically emphasizes students manipulating both science ideas (minds on) and equipment (hands on) (e.g. Lunetta, Hofstein and Clough, 2007). Students' minds-on science: how their construction of understanding can be developed through exploratory talk and dialogue has been highlighted many times in science education research (e.g. Mortimer and Scott, 2003).

Students' preconceptions in concrete science areas and how those can be examined is central in the PD program framing the research for paper II and the analytical tool used by student teachers in paper III is based on research into how students' motivation to learn science can be supported by the teacher scaffolding their exploratory talk (Andersen and Nielsen, 2011). Furthermore it is discussed in all the four papers if - and how - the teachers focus on both students manipulating science equipment and science ideas.

3.4.5 Domain of collaboration

This is the new domain in the meaning-making model.

The importance of teacher collaboration with respect to the teachers' continuing learning from practice has already been noted at several points in this thesis, including in the consensus criteria for how best to support teachers' PD and in the argument to adapt the interconnected model to the new domain of collaboration.

McLaughlin and Talbert (2006) refer to various definitions of what they call a teacher learning community, but state that they all feature a common image of a professional community where teachers work collaboratively to reflect on their practice, examine evidence about the practice and student outcomes, and make changes that improve teaching and learning for the particular students in their classes. This definition is supported by Stoll and Louis (2007).
Referring to former research McLaughlin and Talbert claim evidence that teacher learning communities can support the development of knowledge of practice that is beyond the sum of that of competent and innovative teachers (McLaughlin and Talbert, 2006, p.10). They furthermore refer to concrete examples where the collaboration in learning communities have supported teachers' assessments of their students' conceptual understanding i.e. where a culture of sustained improvement of practice has been established (McLaughlin and Talbert, 2006).

Lumpe (2007) also calls for science education research to move towards facilitating and examining teacher learning communities, bemoans a lack of structures designed to foster science teachers' collaboration focused on students learning at the average school, and connects teacher learning communities to the continuum from pre-service to in-service in his recommendations:

> "Figure out ways to incorporate pre-service teacher education into meaningful professional learning communities at the building level. Design in-service projects that use principles of professional learning communities" (Lumpe, 2007, p.127)

Such *recommendations* to develop practice by working in teacher learning communities in one thing– another important factor when framing and phrasing a new collaborative domain in a model meant to be used to analyze teachers' meaning-making is that of the character of collegial interactions *at a typical* contemporary school.
It is evident in the research base that discussion with colleagues is perceived by teachers themselves as relevant and valuable for the improvement of their own teaching, they typically value the chance to exchange ideas and experiences and

to develop and discuss new materials and receive feed-back from colleagues (e.g. Meirink, Meijer and Verloop, 2007). So the contemporary widespread focus on teacher learning communities in literature about teachers' PD is not only based on 'outsiders' looking into how best to support teachers' professional development. Furthermore evidence is slowly emerging that indicates that the impact of professional learning communities is measurable beyond teacher self-reports: there is also evidence of an impact on teacher practice and student learning (Vescio, Ross and Adams, 2008). But - still - a large part of teachers' interactions with colleagues at the average school seem to have a more informal character than in teacher learning communities as they are defined by McLaughlin and Talbert (2006) and others. School based learning communities *are* extremely difficult to establish and sustain (McLaughlin and Talbert, 2006; Stoll and Louis, 2007) – and there seems to be a need for continuing support from outside the school (Vescio et al., 2008).

Van Driel and Beijaard (2003) when talking about teacher collaboration distinguish two types of collegial interactions: *evidence-based interactions* where teachers are doing some kind of collaborative action-research, exploring questions and analyzing and evaluating results, as it is outlined in relation to professional learning communities by McLaughlin and Talbert above, and *experience-based interactions* referring to teachers more informally exchanging ideas and experiences. This distinction is somewhat parallel to a distinction made based on Eraut's work analyzing informal learning in the workplace, where he identifies four types or work activities that regularly give rise to professionals' learning (Eraut, 2004). He distinguishes between team-working towards a common outcome and informally working alongside others and thereby becoming aware of different kinds of knowledge and expertise and gaining a sense of colleagues' tacit knowledge (Eraut, 2004). Based on the research from Meirink et al (2007) it seems that the more informal experience-based interactions, where teachers get to know colleagues' experiences, can be the starting point for a succession of learning activities in collaborative settings, which can also include experimenting with new teaching methods in their own classrooms. Stoll and Louis (2007) also show examples where the development of

teacher learning communities can be supported for example by facilitating (from external domain) a culture of teachers' sharing and discussion of various artifacts from practice.
In this thesis, teachers' references to outcomes from collegial interactions have been analyzed with respect to the domain of collaboration *also* in the examples of more informal experience based interactions. This is mirrored in the phrasings used to describe the domain of collaboration in fig. 2 above, and in the adaption of the model for use in the various sub-studies (codebooks etc.).

3.5 Danish Science Teachers

In the introduction I argued, that there is not much research that looks at science specific teacher development in the Danish setting, I will, however, refer to a few studies in this section. But first the local 'state of the art': As is the case internationally a number of Danish policy documents have focused on science teaching (e.g. Andersen, 2008; Følgegruppen, 2012). There have been references to a recent international review that concluded evidence that three types of teacher competence contribute to school students' learning: two of those competencies relate to classroom management and personal relational qualities, but the third is 'subject specific didactical competence' (Nordenbo, Larsen, Tiftikci, Wendt and Østergaard, 2008) - *and* the Danish teacher education has been criticized for too little focus on such subject specific didactical competence (Andersen, 2008; Følgegruppen, 2012). In the light of this I will now refer to some Danish research that are relevant to the issues discussed in the thesis.

Firstly the construct of self-efficacy elaborated on above (section 3.4.1) has been applied in a project aimed to examine how science teaching self-efficacy beliefs among new Danish teachers of elementary science (Science & Technology in the Danish school system) interact with the environment of the schools where they get their first appointment (Andersen, Dragsted, Evans and Sørensen, 2004; Ellebæk and Evans, 2005). 'Environmental factors' refer to the teachers' context beliefs, including the perceptions related to factors like support from colleagues,

school-leader and parents, and to the science specific environment at the school: the science labs and materials.

The self-efficacy of a larger group of new science teachers was assessed three times during their first year in practice, together with an examination of the science teachers' perception of their teaching environment (context beliefs: section 3.4.1). This was combined with case studies of three teachers including classroom observations and interviews (Andersen et al., 2004).

The results from surveys and case studies indicated that the general picture is rather low self- efficacy related to teaching science and that changes during the first year were influenced by the new teachers' perceptions of environmental factors helpful to teaching: the support they got (Andersen et al., 2004). Building on this research - and on results from a US program for support of new science teachers and a Danish development project indicating a need for support among new Danish Science & Technology teachers - a model to illustrate and frame such support is suggested (Ellebæk and Evans, 2005). The model and its discussion renders possible a connection between support at the school, *plus* continuing support and feedback from the UC, and the new science teachers' self-efficacy beliefs and innovative approaches to teaching science (Ellebæk and Evans, 2005). Furthermore the model hypothesizes that support during the first practice might retain more young teachers as science teachers (Ellebæk and Evans, 2005). In relation to the latter Ellebæk and Evans (2005, p.41) refer to earlier data that shows a tendency for Danish Science & Technology teachers to give up teaching science after a few years.

The challenges experienced by teachers teaching Science & Technology in Danish primary schools are apparently huge (Sørensen, Horn and Dragsted, 2005). Teachers often refer to their own competences to teach this broad subject, this is particularly the case for teachers without a science specialization from pre-service teacher education, but also some teachers who have such a specialization (Sørensen et al, 2005).

In relation to pre-service teacher education a heavily discussed area in the Danish context, as is also the case internationally, is the complicated issue of theory and

practice – an issue referred to in general in section 3.4.3 above. Findings from a recent research project (Laursen, 2007) are of particular relevance to this issue. The aim of the research from Laursen (2007) was to examine what Danish student teachers mean by 'theory' and 'practice' and how they believe the relationship should be in teacher education. The findings are that the Danish student teachers view teachers' work as very complex and demanding, but that they, when discussing the competencies needed for teaching, often refer to personal relational qualities more than professional competence related to subject matter teaching. However many of the student teachers when getting close to graduation begin to worry about their own subject matter knowledge anyway.

The student teachers typically use the term 'theory 'to describe something produced by others: subject matter and pedagogical theory they have to learn at college and then apply in practice. They typically criticize the UC-teacher education for not mirroring practice in schools, and prefer teacher education to be about tools they can use directly to master the challenges in the classroom (Laursen, 2007). Laursen states, that the conclusion is not straight-forward, that he understands why the student teachers are concerned about learning the craft of teaching and prefer theory that can be used to master this challenge, but that it also might be argued that student teachers ought to be educated to be co-constructors of the professions' theoretical-practical knowledge (Laursen, 2007).

To sum up: It seems that Danish student teachers typically think about their own education as 'application of theory into practice' - or the lack of possibility for application. They do not refer to themselves as someone inquiring into - and contributing to developing practice. Furthermore they rarely refer to subject specific teacher education before being close to facing the reality of practice. But when followed in the first practice many Danish science teachers show low self-efficacy belief; science specific support is experienced as important by the novices. International research confirms that science specific didactical competence is important to support student learning (Nordenbo et al., 2008).

These perspectives, with particular reference to Danish science teachers, will be taken into consideration during the discussion of the findings referring to the first overarching research questions (section 6).

The next section will consider the methods used in empirical research as contextualized by the discussions on science teachers' meaning-making and how to examine it outlined above.

4. Methodology

First I will discuss the overall design of the research presented in the thesis and from there I will move to the specific methods applied and to data-analysis. Finally I will discuss issues related to quality assurance.

4.1 Mixed method design

Mixed methods research brings together quantitative and qualitative research approaches for example by following a survey with interviews.
One general definition of mixed methods is that:

> "Mixed methods research is the type of research in which the researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g. use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purpose of breadth and depth of understanding and corroboration" (Johnson Onwuegbuzie and Turner, 2007, p. 123).

Researchers do not agree on whether mixed methods constitute a distinctive research tradition beside the quantitative and qualitative traditions. Those who argue mixed methods should be treated as a separate and third tradition beside the quantitative and qualitative paradigms have developed various typologies of combination of methods (Creswell and Clark, 2007; Johnson and Onwuegbuzie 2004; Tashakkori and Teddlie, 2003).
The use of mixed methods is inevitably related to a pragmatist philosophy, but not all pragmatists accept such typologies as important (Newby, 2010). Some pragmatists simply see the use of qualitative or quantitative methods or the mixing of them as reflecting dimensions and nuances that offer the best opportunity for answering important research questions, not as some new independent typology (Newby, 2010).
Mixed methods was first conceptualized as *across-method triangulation* in contrast to *within-method triangulation* that refers to the use of either multiple quantitative or multiple qualitative methods (Johnson et al., 2007). In this thesis I refer to within-method triangulation below under quality assurance (4.4.3). There I will discuss the mixing of various qualitative methods used in the

empirical research - often called multiple methods - and how triangulation can contribute to quality assurance. But here I refer to the mixing of qualitative and quantitative approaches under the headline of the term 'mixed methods', and framed as a design issue. This must be seen as a follow up on the discussion of the break with the incompatibility thesis argued above under philosophy.
Researchers arguing for the use of mixed methods often specifically refer to such a break:

> "Both sets of purist view their paradigm as the ideal for research and, implicitly if not explicitly, they advocate the incompatibility thesis, which posits that qualitative and quantitative research paradigms, including their associated methods, cannot and should not be mixed " (Johnson and Onwuegbuzie, 2004, p.14).

Mixed methods research recognizes both quantitative and qualitative methods as important and useful, the goal of mixed methods is not to replace either of those approaches but to draw from the strengths and minimize the weaknesses of both (Johnson and Onwuegbuzie, 2004).

4.1.1 Mixed method design and the research for the present thesis

I will here shortly discuss the research for the present thesis with reference to the typologies describing various mixed methods designs.

Mixing can according to Johnson et al. (2007) both be applied within a single study or across a closely related set of studies. Both kinds of mixing are represented in this thesis. Johnson and Onwuegbuzie (2004) categorize various mixed methods designs in a matrix with the two axis 'time order': from sequential to concurrent, and 'paradigm emphasis'.
The design used for the thesis as a whole is *sequential* in time, using various methods for data collection and analysis to answer various research questions across a closely related set of studies (see fig. 1 above in section 1.4 and table 1 below). Seen as a whole, qualitative approaches are dominant: QUAL+ quan research. The research in paper IV considered alone is however *concurrent* in time, more equal in status of quantitative and qualitative approaches, and within

a single study. In the research reported in paper I the data-collection is quantitative, but qualitative analytical procedures are included to categorize and code the open reflections in the survey.

4.2 Methods

This methods section is aimed to provide an overview – outlined in table 1. More detailed descriptions of data-collection and analysis related to each of the sub-studies are included in the individual papers.

Table 1: An overview of methods

Overarching research questions	**Participants/ Sample**	**Inter-vention**	**Data-collection**	**Data-analysis and quality assurance**	**Paper**
What kind of challenges and needs related to Danish UC-educated teachers' continuing development as science teachers can be identified?	• A full local cohort of science teachers • First round of the survey just before graduation (n= 110) • Second round of the survey when in second year in practice (n=87: the ones who answered in the first round)	No inter-vention	QUAN Data: • Survey: Semi structured web-based questionnaire • Some Likert-scale questions • Central questions open-ended - seeking word based answers	Data-analysis: • Categorization and coding of open reflections (qual) • Frequencies, percentages and cross tabulations (quan) Quality assurance: • Investigator triangulation (qual) • Significance: chi square (quan)	Paper I Paper IV
What characterizes Danish science teachers' meaning-making, when involved in facilitated collaborative inquiries using artifacts from practice? How can Danish science teachers' meaning-making be represented?	• A science team at a local school • Full science team participating in workshops • Pre and post interviews • Four main respondents in post interviews	Facilitated experi-ments in local class-rooms and a range of work-shops over a year	QUAL Main data: • Repeated interviews Additional data: • Video-artifacts from local classrooms • Audiotaped workshop-discussions	QUAL: Interview analysis: • An analytical model, with several domains, provided categories for the initial analysis • Afterwards the content of the utterances in each domain were analyzed using a process of constant comparison Analysis of workshop dialogues: • Critical moments related to issues emphasized by the teachers Quality assurance: • Investigator triangulation • Methodological and data-source triangulation	Paper II
	• Four student tea-chers in their last year of pre-service education	A week of full-day facilitated analytical workshops	QUAL Main data: • Repeated interviews • Video and audiotaped workshop-discussions Additional data: • Project reports • Video-artifacts from STs school practice teaching		Paper III
	Repeated for two of them in their 2nd year in practice	No inter-vention	QUAL Interviews concerning own cases/teaching experiences		Paper IV

4.2.1 The cohort survey

When the same respondents, a group of people with some common characteristics, are involved in successive inquiries at different points in time it can be seen as a cohort study (Cohen, Manion and Morrison, 2007). Here data from a full local cohort of graduating science teachers from a large teacher education institution were collected both at their graduation and in their second year as educated teachers (see table 1). Data were collected through a semi-structured web-based questionnaire with some single item and likert scale questions, but with open-ended responses to central questions. This is the background for combining quantitative and qualitative approaches in data-analysis and in quality assurance in the cohort-survey (table 1).

Data from the first round include answers about background in science, considerations about themselves as science teachers in various fields and reflections on some short science teaching scenarios (see paper I).

Data from the second round is repeatedly considerations about themselves as science teachers: do they teach science, and how much, and if not, how do they reason for not doing it. Furthermore they were asked about how they were introduced as a novice at the school, and how they were included in collaboration at the school. For those that do teach science data includes open-ended reflections about experiences from own science teaching: something that went well and something that did not, and their arguments about why they perceive it as a success or not a success.

4.2.2 Semi-structured interviews

Semi-structured interviews (Kvale and Brinkmann, 2009; Cohen et al, 2007) were used in the research reported in paper II, III and IV to enable participants to express the meaning they ascribed to their experiences, aligned to the research aim of understanding and developing a trustworthy representation of their meaning-making. This research methodology acknowledges that the significance of the meaning lies in the ideas, intentions, values and beliefs of the agent and their interpretation of their own actions and experiences.

All semi-structured interviews were based on interview-guides, but with issue-oriented open questions aimed to reveal each participant's unique experiences (Kvale and Brinkmann, 2009). Details referring to the themes of the various interviews are reported in depth in each of the papers.

4.2.3 Other qualitative data

Workshop dialogues from the study reported in paper II were audiotaped, and workshop dialogues and interactions between the student teachers from the study reported in paper III were both audio and videotaped.

In paper II the main data are the repeated interviews, while the workshop dialogues, and the various artifacts from practice that were analyzed and discussed in the workshops, were used as supplementary data. These data were among other things used to stimulate the participating teachers' recall during interview, as described in the methodology in paper II.

In paper III *critical moments* from the analytical workshops are analyzed and used as part of the main data in alignment with the research questions for this sub-study. Critical moments are in the methodology for paper III defined as workshop dialogues referring to issues and outcomes emphasized by the student teachers in the interviews. Critical moments are chosen from the full filmed workshop session during data-analysis – for more details see paper III.

4.3 Data-analysis

The methods selected for data analysis, and interpretation of data, in mixed methods research relate to the particular research questions and to the types of data chosen for the investigative process (Creswell and Clark, 2007). Data analyses referring to each of the types of data are shown in headings in table 1, and the various analytical procedures and steps are described in detail in each paper.

I will however here elaborate on two overall perspectives: 1) some general considerations about the meaning-making model and how it is used in data-

analysis proceeding from section 3.4 above, and 2) data-analysis in relation to the overall mixed methods design applied.

4.3.1 The meaning-making model as an analytical tool

The meaning-making model is outlined in general terms above, here I will elaborate on how the model was applied as a tool in analysis and to make representations in three of the papers (paper II, III and IV).

In the present empirical research the model is used to analyze the *utterances of the teachers* during interviews. When a teacher's reflection involves two domains, a reflection arrow is used between the domains; when the teacher refers to how something in one domain entails some actions in another domain, an enactment arrow is used. In relation to the latter I apply the broad understanding of action from Wertsch (1995), so both the teacher's utterances about something they have done as a consequence of something else, and what they plan to do are included. The final representation is called a *meaning-making map* referring to the research aim: to examine and represent the teachers' meaning-making.

When ending section 3.2 above I pin-pointed three challenges: one was how to represent an ongoing process, another was how to include both reflections and new enactments, and the third was the interconnection between an individual's meaning-making and the intertwined level of social development.

In relation to the two last issues it is important to emphasize that it is *the teachers' utterances about enactment and collaboration that are the units of analysis* when using the model as it is described in the codebooks (the codebook used for the study presented in paper II is in the paper, and the codebooks used for the studies in paper III and IV are in appendix 5).

From the philosophical considerations and theoretical background described above many arguments can be made for including *observations* in the classroom in relation to the domain of practice, and *discourse analysis* of some kind in relation to the domain of collaboration. Likewise broad insight into the personal domain calls for multiple methods as is exemplified by research into teachers' PCK. And teachers' utterances about input and facilitation from the external

domain, will in this instance only describe *their* experiences, not the intentions when designing the PD. Various kinds of additional data is therefore a part of all the papers as described above: The meaning-making maps *represent the teachers' experiences*, their interpretations, how they describe their enactments in the classroom etc. *Interpretation* of the meaning-making maps is the next step in the papers, and this is where multiple methods are essential.

To sum up: The model in fig. 2 above must be seen as a general model outlining issues hypothesized - warranted by the theoretical and philosophical background - to interact concerning teachers' meaning-making. When using the model to analyze teachers' meaning-making in a concrete research context some choices have to be made and all representations have some limitations. In relation to representing an ongoing process a meaning-making map is a 'snapshot' based on an interview, at a certain point in time. But the interviews are conducted so the teachers are encouraged to both look back and forward from that point of time enabling the later discussion of their meaning-making to include their agency in relation to continuing change.

The model is used in this way in papers II, III and IV, albeit with some small variations in the outline of the meaning-making maps due to the particular contexts; in paper II and III the focus is the teachers' experiences from particular developmental projects while the focus in paper IV is the teachers' general experiences from learning as a teacher.
The hypothesis is that snapshots like the meaning-making maps can help interpret the complex processes involved in a teacher's meaning-making in both such contexts.

The outline of the model and the experiences from adapting it in this certain way in the research for the present thesis - pros and cons - will be further discussed below in chapter 6, in the discussion of the third overarching research question.

4.3.2 Data-analysis and the mixed methods design

In a sequential mixed methods design with a closely related set of sub-studies, as in the overall design for this thesis, the analysis and results of data-analysis from a first phase of the research process can be used to guide data collection and analysis in the next phases (Creswell and Clark, 2007; Johnson and Onwuegbuzie 2004). Here results from the first round of the cohort-survey examining the new science teachers' reflections on teaching science and themselves as science teachers were used to identify a range of challenges and possibilities related to their continuing professional work as science teachers. Particular results from this were further pursued and referred to in the rest of the sub-studies. Likewise the approach to data-analysis and the procedures adapting the meaning-making model, developed during the work with the data for paper II, were subsequently also used in analysis of data for paper III and IV.

In relation to the concurrent data-collection for the sub-study reported in paper IV, data-analysis was planned so the findings from the qualitative in-depth part of the study, identifying some challenges and possibilities related to the novice science teachers continuing learning in practice, was used to guide the parts of the in-depth data analysis regarding the second round of the cohort study. For example possibilities related to collegial interactions around science were identified in the qualitative analysis and - consequently - the degree to which teachers from the cohort were involved in such interactions was pursued in the quantitative analysis.

An additional challenge in a sequential mixed methods design is analysis and interpretation *between* the approaches in relation to results referring to the overarching research questions (Creswell and Clark, 2007). This final analysis looking holistically at the sum of results from the sub studies published independently in the papers included identifying similarities, differences, and interconnections across the four papers (Newby 2010). Findings from this final analysis are presented and discussed below (chapter 6).

4.4 Quality assurance

Considerations about quality assurance in a mixed methods design must also refer to the respective methodologies as illustrated in table 1.

4.4.1 The questionnaires

In relation to the quantitative results from the web-based questionnaires – discussed in paper I and IV – quality assurance has been taken into consideration both in the design of the questionnaires and in discourse regarding the validity and reliability of the results. The questionnaires were designed with careful consideration of the use of closed categories, Likert scale questions, and open categories, and they were piloted and pretested before use following the recommendations from Newby (2010, p. 332). Part of the piloting was to audio-record a pre-tester - someone who had a comparable level of experience as a teacher as the respondents - talking out loud about the interpretation of questions while answering a first version of the questionnaire. This pre-test led to small refinements in the questionnaire.

In relation to the sample, which is a central issue in considering the reliability and validity of a questionnaire instrument (Cohen et al, 2007, p.158), a full local cohort of teachers with science specializations is involved. It was decided to include the full local cohort, as the case-study teachers are locally educated teachers. The sample size in principle allow conclusions to be made about science teachers graduating in Denmark that year (confidence level nearly 90 per cent: Cohen et al., 2007, p. 101 ff.), but teachers taking science specializations at the various UC's in Denmark might differ, and the results in the papers I and IV must basically be seen as referring to the local cohort. In the first round of the survey n=110. The 87 answering are the ones who were included in the second round of the survey (table 1). Considerations about non-response bias (Cohen et al, 2007, p. 346) are included in both paper I and paper IV.

In relation to the significance of the results chi-square tests are used in paper I with the conventionally accepted minimum level of significance as 0.05 (Cohen et al, 2007, p.525).

4.4.2 The qualitative research: Pragmatic and communicative validity

In qualitative research, such as the main parts of the research in this thesis, objectivity must be seen as reflective objectivity - that you as a researcher strive for *objectivity concerning the subjectivity* (Kvale and Brinkmann, 2009, p. 268). This includes making one's own role as transparent as possible through explicit reflections.

Validity and reliability are sometimes challenged as constructs for qualitative research, and there can be arguments to substitute the terminology of validity and reliability with terms like credibility, dependability and confirmability, but I will, with reference to the considerations about dimensions of quality assurance by Newby (2010) and Kvale and Brinkmann (2009), stick to the 'old' terms, while bearing in mind Newby's comment that:

> "Objectivity in the quantitative sense cannot be achieved in qualitative research because there is no external standard such as statistical significance to appeal to (..) with sufficient information on how data were collected and analyzed we can (however) make this judgment and understand the personal framework within which the researcher was objective" (Newby, 2010, p. 121).

The aim in all the papers in this thesis has been to aim for this level of thoroughness in describing how the qualitative data was collected and analyzed.

Considerations of what is valid knowledge, the logic of justification, have been the theme in many discussions in western philosophy. Several different kinds of phrasings are used to refer to validity in qualitative research (e.g. Cohen et al., 2007, p.133). Various kinds of 'truth-criteria' do not have to exclude each other, and I will therefore discuss the qualitative research for this thesis with reference to more than one kind of validity criteria.

With reference to section 2 above, and philosophical considerations of pragmatism, I will start with pragmatic validity (e.g. Kvale and Brinkmann, 2009; Worren, Moore and Elliott, 2002). In pragmatic science, the goal is to develop knowledge that can be used to improve a particular situation in practice.

Pragmatic validity is therefore about the usefulness of research in practice and the quality of new practice based on the research (Kvale and Brinkmann, 2009, p.284). According to Kvale and Brinkmann (2009) pragmatic validity is supported by contextualizing the research and making clear the context-dependability in descriptions and interpretations – and by building considerations about the practical application of the research into the research process.

The sub-studies reported in paper II and III explicitly concern particular local context and situations. The rationale in the beginning of this thesis starts with the international consensus criteria relating to design of professional developmental activities for teachers, and the overarching second research question refers to the aim of examining implementation of these principles in a Danish context. So considerations about pragmatic validity has been built into the research process, and the report of findings; it is however the case that the degree to which the findings relevant for design of PD can and will be applied looking forward occurs after the presentation in the papers and this thesis.

The discussion about pragmatic validity in Worren et al. (2002) refers among other things to the representational mode used, the visual representation of data, and how the research consequently might be used by members of the community to support development in practice. As such pragmatic validity is closely related to *communicative validity:* trying out validity in dialogue (Kvale and Brinkmann, 2009). The desire for communicative validity has also been built into the research process, at the level of the participating teachers by using validating questions through the interview process, and in data analysis by including fellow researchers, as discussed below (4.4.3). In relation to interpretation of the results, these have been discussed both in local arrangements with practitioners and at international research conferences (see list of publications in appendix 6). Furthermore comments and input from the peer-review process has lead to refinements.

I will now supplement this discussion about pragmatic and communicative validity with a short reference to additional ways of supporting validity and reliability in the research process.

4.4.3 Triangulation

The notion of *triangulation* covers how a process or an outcome can be validated through using at least two independent sources (Cohen et al., 2007). The process of using various kinds of triangulation can also form a bridge to discussions of reliability (Cohen et al, 2007, p.141).

In all the sub-studies in the present thesis *investigator triangulation* (Stake, 1995) has been applied by involving a fellow-researcher in data-analysis. Cohen et al (2007, p. 148) refer to *inter-rater reliability* in their considerations about reliability in qualitative research in general, and Kvale and Brinkmann (2009, p.271) contextualize the term in relation to interview research in particular.

In all the analysis of qualitative data for this thesis inter-rater reliability has been calculated and coding has been refined in an iterative process (Cohen et al, 2007). Furthermore the overall design of the study involves both cross-section studies and case studies over time (fig.1 in the introduction), referred to as time-triangulation by Cohen et al (2001, p.142). And methodological and data-source triangulation (Stake, 1995) within the qualitative approaches can also be referred to: Both the same method in different contexts and different methods referring to the same questions have been used, and various kinds of data are involved in all the sub-studies, for example interview, video and audiotaped workshop dialogues, and project reports in the study reported in paper III.

4.4.4 Participant researcher

My involvement as both a researcher and a facilitator in the video-groups described in papers II and III was a natural consequence of the second overarching research question - to study teachers' meaning-making in frames of PD activities designed according to what I have called the consensus criteria. A participant researcher can, as stated by Cohen et al. (2007, p. 135) support the credibility of the findings, and in the present research the double role as facilitator and researcher provided a unique insight into the concrete contexts at

the local school, and in relation to the student teachers' process from teaching – and video taping - in their school practice, to their involvement in collaboratively discussing their experiences.

It is however important to be aware that a facilitator in collaborative video-analysis may have an influence on the participants' interpretation of experiences (Sherin et al, 2009).

In the collaborative video-analysis framing, the study reported in paper III, my role as a facilitator was that of providing a symbolic tool for video-analysis and keeping the dialogue structured - description from various angles before interpretation etc. (Rodgers, 2002) – not to interfere in how the student teachers finally interpreted the classroom incidents. The findings can, as discussed in paper III, still be biased by the fact that the workshops physically took place at the college and I might very well have been seen by the student teachers as belonging to the college making them focus more on college aspects than if the workshops had been situated at for example one of the placement schools. Such bias is hard to avoid. Furthermore the reference they all make to benefitting from using the analytical tool might be seen as biased, since the tool is partly developed, and at least presented to them by me - the person also conducting the interview. An attempt to supplement their own reference to benefitting from using the tool has as described in the paper been made by looking into their project reports, and how and if they actually apply the tool in their final analysis (triangulation). Both this analysis of their project-reports, and the analysis of the interviews, where among other things the student teachers refer to the analytical tool, has also been made by a fellow researcher not involved in the intervention and the facilitation.

In relation to the sub-study reported in paper II the facilitator role was here more significant and the intervention lasted over a longer time-period. As a facilitator I made frequent visits to the case school during the year of the local PD project, provided materials for trials in local classrooms, had some input in workshops about research results, filmed the classrooms etc. As can be seen from the results below several of the participants consequently refer to input and support from me as a facilitator when referring to their outcomes from the PD project. The

technical support in managing the filming might be seen as the least intervening aspect, but just to clarify, it was agreed upon to avoid technical stuff from being the threshold for the teachers. The student teachers in the study from paper III were responsible for their own filming, they were younger, 'ITK- natives', and they stated that this was not a threshold for them. Furthermore, as a facilitator for the science team at the local school, I was involved both in the formal workshops and day-to-day discussions when supporting individual teachers. There was - so to say - no one else to support the in-service teachers from the external domain. Regarding the student teachers, their trials in the classroom, and the choices of what to videotape referred to their problem statement for their bachelor projects, and besides these analytical workshop facilitated by me they followed the normal fourth year curriculum for the pre-service program.

To sum up I will say that my experience from the research process has been, that my involvement as a facilitator, and also my background as a science-teacher and a teacher educator, has helped me to recognize essential aspects in the collection, analysis and interpretation of data. But I'm aware that the role as a participant researcher, and the influence on the issues studied, has to be thoroughly considered and therefore I have attempted throughout the thesis to make my own role as transparent as possible.

5. Findings

Findings will in this section be presented as a short summary from each paper while findings referring to the overarching research questions will be summarized below in the discussion in section 6.

5.1 Paper I - A cohort of novice Danish science teachers: Background in science and argumentation about science teaching

Paper one aims to establish a foundation upon which, an understanding of the meaning-making of Danish science teachers may built and developed upon in the subsequent three papers. It should be borne in mind that the science teachers studied are educated in integrated UC-programs, and that there may be noticeable differences between the orientation of these teachers toward science teaching and learning and science teacher with a university subject-specific background referred to in much research. There has been little research on these UC-trained teachers, who in Denmark are often referred to as belonging to a humanistic tradition and in the background section in the paper it is problematized if the focus on the use of a transmission orientation to teaching science identified as the main challenge for reforming science teaching in recent policy papers (e.g. Rocard, et al., 2007) can stand alone. A completely different problem relating to primary teachers in particular - is that there is a noted tendency for the teachers to have a purely activity driven orientation, with school students spending a lot of time doing science, but little time thinking, talking posing questions or constructing explanations (Abell and McDonald, 2006).
The research questions for the exploratory background study are based on this:
1) What characterizes new Danish UC trained science teachers' science background?
2) How do new Danish UC trained science teachers reflect on themselves as science teachers?
3) How do new Danish UC trained science teachers reflect on science teaching?

A local cohort of graduating teachers with the four science specializations Biology, Physics & Chemistry, Geography and Science & Technology (n=110) participated in a survey examining their science background, their reflections on specific scenarios of science teaching, and their argumentation about themselves as future teachers in various science fields. Data were collected through a semi structured web-based questionnaire with single item questions revealing background information, but with central questions seeking open-ended answers. Those open reflections were approached as qualitative data using mainly data-based coding in analysis - with the categories and codes developed described in a full codebook published in the paper.

The findings show that around 30 % of the teachers in the cohort has what is defined as a high level background in science before teacher education: 63 % of the teachers with Physics & Chemistry has this background, while the majority of the teachers with the three other specializations started in teacher education with only a mandatory science background from upper secondary. These background data are supported by nearly half of the teachers spontaneously emphasizing their humanistic background.
In relation to reflections on themselves as science teachers a large percentage of the teachers felt prepared to teach Science & Technology and Geography even without a specialization, based on personally being interested. Fewer are willing to teach Biology and even fewer Physics and Chemistry. The arguments used refer to lack of subject matter knowledge and for Physics & Chemistry the argumentation used is often quite value-loaded referring to knowing absolutely nothing about this field. The Physics content is seen as especially complicated and difficult, and earth science as easier to cope with. When looking into the teachers' feelings about the four various specializations it is evident that this apparent low self-efficacy in the physics area is expressed most by the teachers with Geography and Science and Technology specialization, while more Biology teachers, like Physics & Chemistry teachers, feel prepared to teach out of specialization, though the Biology teachers do not on average have a similar high level background as the Physics & Chemistry teachers.

Results from analyzing the teachers' reflections about the various scenarios support these findings and indicate that many of the new teachers have a low self-efficacy in the Physics & Chemistry area. The teachers from this cohort are not alone in experiencing Physics as the complicated field of science, the nature of Physics and the high level of abstractions and idealization is partly a reason for this (Duit, Niedderer and Schecher, 2007), but a large subgroup in the cohort seem to have so low confidence that it affects how they see even scenarios related to relatively simple physics subject matter such as teaching electrical circuits in 4th grade. This might very well affect the approach to teaching primary Science & Technology a subject that in principle all teachers in the cohort are qualified to teach. In relation to orientations towards science teaching the results confirm the hypothesis of activity-driven science as the ideal for many of the teachers – activities are assumed to make science interesting and motivating, with reference to what the students can do, not so much what they can learn. In a continuum of orientations from a student centered conception, seeing students as more or less self-directed learners and the teacher as a coach, to a teacher-centered conception, with the teacher as dispenser of knowledge and the students as working with teacher specified activities (Anderson, 2007) most of the new science teachers are placed near the first. Compared with contemporary recommendations for development of science teaching the widespread tendency to consider students' engagement and motivation can be seen as a strength, but the activity orientation - many of the teachers being convinced of the value of hands-on activities, but not being aware of what science students are supposed to learn from the activities - must cause concern as the teacher's specific focus on students' learning is seen as decisive for developing (science) teaching (Borko, 2004).

In the conclusion the great variation between the teachers in the cohort, and presumably the science teachers at a random local Danish school, is emphasized. Implications in relation to supporting science teachers in developing confidence alongside understanding of subject matter, and supporting teachers with different learning trajectories in developing PCK for science teaching (Abell, 2007; Berry et al, 2008), are highlighted.

5.2 Paper II - Science teachers' meaning-making when involved in a school-based professional development project

Paper two proceeds to examine how to support science teachers' professional development at a local school. Teachers in a local science team participated in a year-long PD-project, initiated by a local resource teacher and the researcher, who also facilitated the workshops, in which the teachers had access to new tools and materials for science teaching. Video and other artifacts were collected from trials in local classrooms and subsequently included in structured discussions in the science team. The research aim is to examine the science teachers' meaning-making when involved in these collaborative inquiries: what they identify as outcomes, how they make use of inputs and support in their classroom teaching and in collegial interactions, and how it might affect their ideas about teaching and learning science.

The theoretical reasoning behind the project is twofold: how best to support and facilitate teachers' learning, and how to research into teachers' learning. Based on this rationale, outlined in the paper the research questions relating to the school science team's collaborative project in which team members were engaged in examining artifacts from practice in local classrooms, are:

1. How do individual teachers reflect on the project?

a) What outcomes do they identify?

b) To which aspects of the project do they refer?

2. What links do the teachers make between a) and b), and what insight into their meaning-making do these provide?

3. What ideas about the teaching and learning of science do the teachers express and how might these influence and be influenced by their meaning-making related to the project?

Facilitated experimentation with new tools in local classrooms, and the collection of film and other artifacts were gathered over a year between a range of workshops for the teachers in the science team. The facilitator structured the discussions in the workshops and offered relevant input and presented tools from

the knowledge base of research in science education regarding typical student preconceptions and alternative conceptions in science (Driver, 1989; Scott, Asoko and Leach, 2007).

Data were collected through two rounds of individual semi-structured interviews to enable participants to express the meaning they ascribed to their experiences. The first round took place before the first workshop to collect background data. Four teachers were then selected for an in-depth study using purposive sampling (Cohen et al., 2007) to represent diversity: Teacher A in her first year of teaching primary science, teacher B: a non-specialist in her third year, teacher C: an experienced teacher, using some of her time to support colleagues as resource teacher after she recently finished an in-service diploma in science education, and teacher D: the most senior teacher teaching lower secondary. The teachers' ideas about teaching and learning of science were explored in both interviews. In the second interview this was followed by questions related to their experiences from the project. The interconnected model (Clarke and Hollingsworth, 2002) was adapted with a new domain of collaboration to facilitate analysis and representation of the complex interplays related to the teachers' meaning-making as meaning-making maps (section 3.4 above).

Findings are presented as commented meaning-making maps, which can be seen in the paper (appendix 2).
The main outcome experienced by the novice teacher A is getting ideas from colleagues to include structured discursive activities in her science teaching. She refers to getting to know tools like concept cartoons (Keogh and Naylor, 1999), and to the insight gained into students' pre-conceptions from the collected artifacts. Teacher B emphasizes the benefits of being facilitated in her first time teaching electrical circuits to 3rd grade, using small bulbs, wires, and batteries and with students posing hypotheses, experimenting, and discussing. Referring back to previous experiences at a resource center, where her former classes worked with electricity, she states that too much emphasis was on science as a show compared to the new focus on students' thinking.

Nearly all the considerations from teacher C refer both to being a resource teacher gaining an insight into her colleagues' practice and a classroom teacher focusing on her students' learning.
Teacher D from the start was reluctant to have video in her class, but tried anyway and refers to challenging her own performance anxiety as a main outcome. She also refers to studying the students' work processes and discussions: how they gradually developed understanding in the concrete theme of climate science.
The teachers' expressions about the teaching and learning of science in both interviews were analyzed to inform a discussion of their 'forward pointing journey through the project'. Teacher A and B found science a hard subject to teach and felt a lack of subject matter knowledge in the physics area, findings that refer back to paper I. In the first interview teacher A refers very much to her ideal of science as a subject with hands-on activities, but also to experiencing problems with classroom management. In the second interview she has a new emphasis on students' talking science and their thinking and learning, and teacher B and teacher D likewise develop to appreciate students' learning outcomes from their discussions, and from manipulating both science equipment (hands-on) and ideas (minds-on).
Teacher C refers in both interviews to students' experiments and talking science, and how she as a teacher can support students' learning, but again with meta-reflection about how she continuingly can facilitate local development as a resource teacher at the school and how she can use what she knows from the research base in science education.

The conclusions presented as four main assertions are that all the teachers use artifacts from the project in their interpretations regarding students' learning of specific science subject matter in specific situations. They seem to emphasize outcomes related to areas where each of them feels supported in relation to tensions from their professional work as expressed for example through their ideas about teaching and learning of science. Teacher A's ideal, expressed at the start of the project, was self-regulated students doing hands-on science, but she

also emphasized how problems with classroom management forced her to sometimes 'let the students sit' and do written work instead of experiments. Inspiration from colleagues apparently helped her by providing tools to structure 'minds-on activities'. For B the positive experience of teaching electrical circuits (with support) might have balanced her expressed low self-efficacy in the physics area. Teacher C emphasizes outcomes related to being supported as a resource teacher and teacher D to the threshold of performance anxiety she has to pass to share her huge experience with colleagues.

However some patterns in the teachers' meaning-making maps seems to be of a more general character for example related to experimenting with new approaches: purposefully trying out something new in practice combined with reflection about it. In relation to the inputs from external domain during the PD experience the teachers seem to ascribe meaning to, and make continual use of, inputs when those are connected to concrete events in local classrooms with improvement in students' learning opportunities, i.e. students manipulating both science ideas and equipment in ways the teachers appreciate. So teachers' perceptions of salient outcomes, their experiences of improvement in their students learning, seem to be determent for their continual use of input from PD and for their gradual changes in beliefs (the feed-back loop, 3.4.2 above). Furthermore they all seem to be encouraged to continue collaboration around science by the experience of individually gaining from the facilitated collegial interactions.

Implications are discussed both in relation to design of science teachers' PD and research into teachers' meaning-making.

5.3 Paper III - Pre-service teachers' meaning-making when collaboratively analyzing video from school practice for the bachelor project at college

The third paper reports from a study of a group of student teachers (STs) who collaboratively analyzed video from school practice and then used the results in their bachelor projects. The aim is to examine their meaning-making: what they experience as outcomes from the collaborative inquiries and how their interpretation of classroom experiences might be influenced. In the rationale for this particular approach the paper refers back to paper II. The theoretical reasoning refers to contemporary reforms in pre-service teacher education throughout the world, which recognize the importance of classroom practice in the development of competencies – an issue that is also part of the Bologna competency profile for a professional bachelor degree. Likewise the Danish four-year integrated BEd program now aims to increase the emphasis on STs' analysis of classroom interactions.

The complicated interplay between theory and practice, outlined above (section 3.4.3), is included in an argument about how theory and practice has to be continuously interactive, and how small principles t-theory is claimed to be helpful for STs to continuously evolve in the experimental process of learning in the classroom, while generalized abstractions (T-theory) needs to be connected to sufficient practical experiences in which the theory is consciously used (Korthagen, 2008). 'Reflective practice' - teachers' learning from and reflecting on practical experiences - continues to be a contested term and few definitive statements about the effects of different models for pre-service teacher education can be made based on research (Cochran-Smith and Zeichner, 2005), but still - the importance of opportunities for STs to collaboratively inquire into and problem solve based on concrete classroom experiences is recognized in a range of reform programs.

With reference to this, and to research into how teachers' sharing of video clips from classroom practice in collaborative inquiries has been identified as a potential mediating tool (e.g. Sherin and Han 2004), a local initiative to support

STs in collaboratively analyzing video-based classroom artifacts to be used in their individual bachelor project is presented. The research questions in this particular context are:

1) Do the students teachers' interpretations of their classroom experiences change after being involved in the process of collaboratively analyzing video artifacts for their individual bachelor projects, and if so, how?
2) What do the STs themselves emphasize as outcomes from the collaborative video-analysis?
3) What further insight into their meaning-making is gained when looking into critical moments in workshop-dialogue illuminating issues raised by the STs in 1) and 2)?

Four STs called Marie, Christian, Jane and Louise are followed in the last year of pre-service education. During 4 weeks of school practice the STs individually collected video of those parts of their teaching that was relevant to the focus they had defined for their bachelor project, and on return they selected clips for peer analysis which was done collaboratively in a week of analytical workshops facilitated by the researcher. A newly developed analytical tool was used to mediate this analysis (Andersen and Nielsen, 2011). The analysed video clips eventually formed part of their individual bachelor projects phrased and framed in various ways.

Findings are, like in paper two, partly presented as commented meaning-making maps, which can be seen in the paper (Appendix 3).
The STs interpretations of their classroom experiences during school practice seem to develop during the process. All the STs in the first interview just after school practice refer to their worries and considerations related to concrete classroom incidents, and in the second interview, after the collaborative analysis and delivering the project, they reevaluate and reconstruct these experiences. The development goes from something partly tacit that they worry about towards more specific interpretations of issues helping or hindering students learning and their motivation to learn. Two of the STs also include meta-reflection about how

you learn as a teacher. However when referring to outcomes they often do not phrase them in relation to how to act in the classroom, but in relation to insights used in their work on the project, for example peers seeing something new during analysis which they can use in their report. The STs describes the experience as different from former tasks during teacher education. Their utterances are connected to the T-theory versus t-theory issue (Korthagen, 2008). They refer to outcomes from focusing on concrete experiences in school practice, the detailed looking into what actually happened, before applying "theoretical glasses" (this is how they phrase it).

A closer look at *critical moments* from the audio and video taped workshop dialogues, which address issues and incidents they emphasize in the interviews, reveals a process where the STs talk themselves into an understanding of incidents that worry them based upon among other things input from peers and the analytical categories.
An additional analysis of the bachelor reports delivered between the two interviews looks into the STs' use of the categories from the analytical tool and T-theory versus t-theory (this analysis is also done with reference to their perceived outcomes and how those were phrased). The analysis reveals that all of the STs, though spontaneously criticizing former tasks at college as too much T-theory, prioritize certain large grain size T-theories in their reports, besides their analysis of the concrete experiences, where they all use the categories from the analytical tool in their reports.

In conclusion, the structured collaborative analysis apparently supports the STs in a nuanced analysis of concrete incidents and in reconstructing their experiences focused on students' learning. However their reflections are not related to changing their teaching, instead they emphasize outcomes related to mastering the bachelor project. A typical example being the comment that their peers helping them to focus. They refer positively to the task being different than former tasks while starting with concrete experiences before applying theory, but they still prioritize general abstractions in their reports. Apparently it is one thing

to refine the intended learning outcomes to up-prioritize analysis of concrete practice, as it is done in the local program, and then it is quite another issue to change practice in pre-service teacher education accordingly. The STs' reflections imply that the actual practice among teacher educators might not have changed alongside the change of the intended learning outcomes referred to above. At least the four STs have perceived former tasks as late as the previous year as though they were urged to discuss theory and with this as starting point maybe use practice examples, not really to analyze subject-specific practice.

The findings can occasion cautious optimism in relation to STs gaining from new sorts of tasks in pre-service teacher education, but if the aim is for STs to acquire competencies in continually learning in and from practice, there needs to be better alignment between intended learning outcomes, types of tasks and their evaluation.

5.4 Paper IV - Science teachers' construction of understanding and interpretation of experiences in the first practice

Paper four is written in Danish for the peer-reviewed Mathematics and Science Education Journal MONA, with a short English abstract. Therefore the outline of the findings from this paper will be more elaborated here, than the outline of the findings from the three first papers, and the representations as meaning-making maps are likewise translated (fig. 3 and 4 below).

Referring back to the other papers the benefits of following-up on participating STs from the study presented in paper III and from the cohort to look into their situated construction of understanding and interpretation of experiences - their meaning-making - in their first years of practice as science teachers are highlighted. The theoretical rationale refers to teachers' informal and formal learning seen in a continuum where their reflections on incidents and interactions with colleagues in everyday work must be seen to interact with outcomes from more intentional learning activities (Eraut, 2004). Furthermore teachers' learning is seen as situated, mediated and distributed – and with a potential feed-back loop from students' reactions towards changes.
The research questions are:
1) What kind of experiences and learning situations from practice do novice science teachers emphasize?
2) What challenges and possibilities for continuing learning in practice can be identified based on this?
The study is designed with a pragmatic mix of methods (section 4.1 above). The main data are interviews with two teachers, Jane and Christian, who participated in the study reported in paper III, but by this time are in their second year of practice. They are chosen from the group of four discussed in Paper III because both these novice teachers take several science classes, albeit in very different school contexts. Of the remaining cohort, Marie is teaching in an international school for adults (a Danish "Højskole") where there is no science teaching and Louise is only teaching a few lessons in Geography. Christian was specialized in

both Physics & Chemistry and in Biology and has taught these subjects along with Geography and primary science for the two years of his teaching career. Jane was specialized in Geography and has taught several classes in this subject since leaving the teacher education. Also, since the start of her second year out of college she is teaching Science & Technology (primary science). These two science teachers' construction of understanding and interpretation of experiences from their first practice, related to cases of experiencing learning that they emphasize themselves, is analysed and represented with the use of the meaning-making model also used in papers II and III. To put these two teachers' experiences in perspective data from a follow up on the teachers from the cohort (paper I), now also in their second year of practice, is used. Do they teach science and what kind of experiences do those, that do, emphasize? How do challenges and possibilities identified in the case-studies look like in this broader perspective?

In the findings, three cases that Jane and Christian identify as learning experiences are represented as meaning-making maps (fig. 3 and 4).

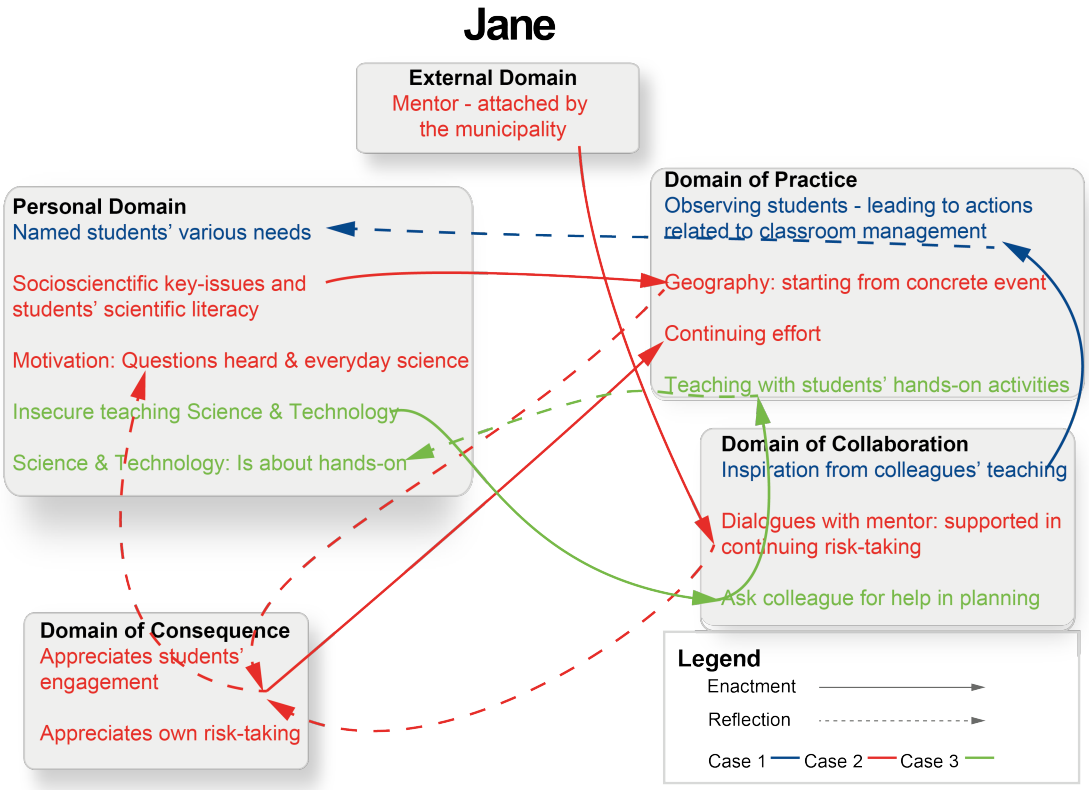

Fig 3: Jane's meaning-making map

The first case Jane refers to is from her first year, where she had the chance to watch colleagues teaching her own students (blue in fig. 3). This inspired her to change her approach to initiatives in her own classroom management and allowed her the possibility to focus on how best to support given students.
Her second case is about teaching Geography (red in fig. 3). She refers to her specialization from teacher education when arguing about a wish to teach geo-science starting from key socio-scientific challenges in our time[2]. When her students posed a lot of questions related to the earthquake and tsunami near Fukishima she improvised. She found her students to be very engaged and reflects on the importance of students' self-determination and motivation related to such socio-scientific dilemmas. Seen in retrospect she emphasizes being content with her own risk-taking, and reports how she was encouraged to continue to take risks in her teaching when sharing the experience with a mentor at the school.
Jane continuously refers to the colleagues in the third case (green in fig. 3). She felt very insecure when starting teaching Science & Technology and found that she did not have the same repertoire and insight as she had in Geography. She eventually asked a colleague for help in planning some lessons together, and she explains how she appreciated this input and is now using the same approach with students' hands-on activities in her planning for Science & Technology.
To sum up the cooperative domain is central in Jane's meaning making. Interactions with colleagues support her in experimenting in the domain of practice. She seems to have developed a certain level of PCK in relation to teaching Geography from pre-service teacher education, exemplified in her reflections about students' motivation to learn in case 2, but her approach to and reflection about Science & Technology is not in the same way related to students' learning. She confirms that her experimentation is more conscious when teaching Geography, for example with structured group-work (cooperative learning) based on experiences from her bachelor inquiries where students' group-discussions

[2] She uses this phrasing from "Bildung"-theory: Westbury, Hopmann and Riquarts, 2000. This is to some degree also covered in the term 'socio-scientific issues' and the aim of students developing scientific literacy, more widespread in the international science education research, and therefore used in the translated map in fig. 3

did not work very well. Her teaching in Science and Technology is the opposite to this, with more copying of what works for the colleague, focused on students' hands-on activities.

Christian's first case is about a trial to organize a science classroom so he can supervise part of the class in classifying fungi and using a microscope while the rest is doing seatwork (blue in fig. 4). This didn't work in an optimal way and he reflects on the challenges the students experienced, mainly related to social processes in groups, and on how based on these experiences he can qualify his teaching and their learning in the future.

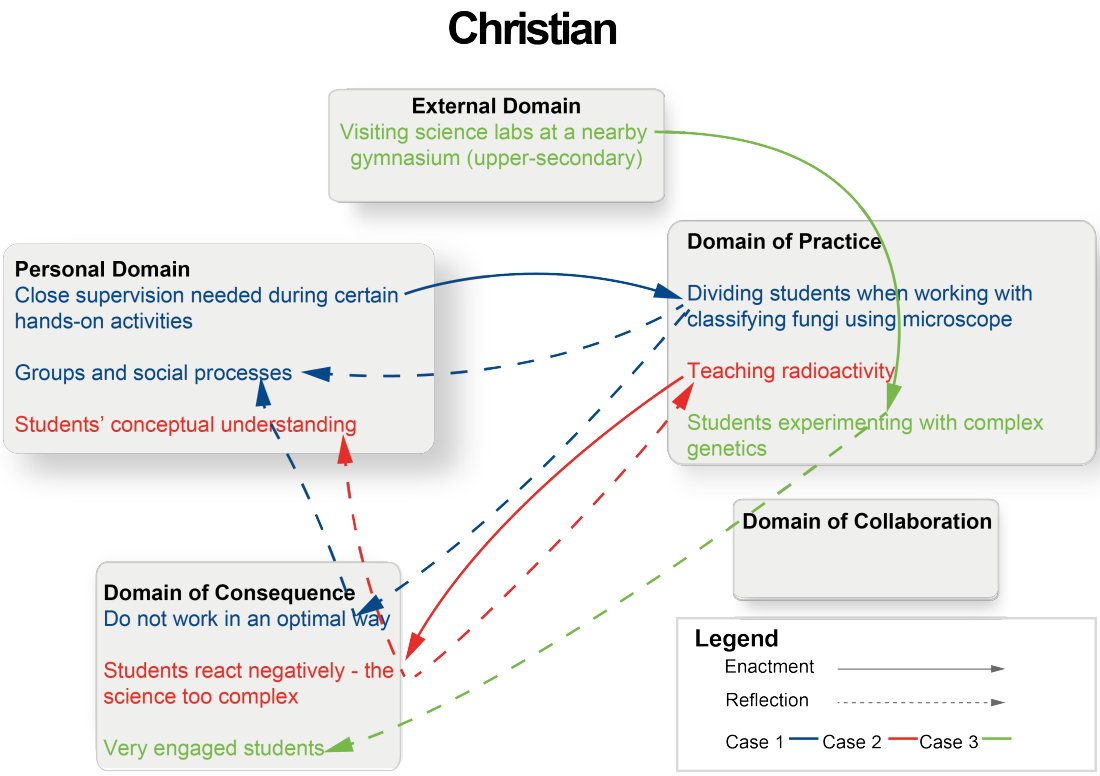

Fig 4: Christian's meaning-making map

Christian's second case is about teaching Physics and suddenly realizing that the students do not grasp the fundamentals of radioactivity - his approach was far too complex (red in fig. 4). He is again looking forward and reflects on how to better support the students' learning – their conceptual understanding related to this complex science subject matter.

Christian explicitly states that he learns most by trying something out and qualifying what does not work, but emphasizes in the last case (green in fig. 4) that he also had a positive experience involving external domain. He visited a nearby gymnasium with his students and the facilities there made it possible for them to experiment in a genetics lab. He reflects on valuing their motivated behaviour in the lab.
Christian, unlike Jane, does not spontaneously refer to collegial interactions, but when asked he positively refers to sharing his own practice, and being inspired by colleagues' practice, at meetings in the science team. Furthermore he like Jane refers to making inquiries in his bachelor project, but he specifically emphasizes that he did not in general experience pre-service education as supporting an inquiry approach to learning as a teacher.

In the paper Jane and Christian's experiences are put into perspective by the results from the second round of the cohort-survey. They both ended up teaching science, and are relatively content with this. Around 30 % of the teachers in the cohort do not teach science in their second year in practice even though that is their specialization. Some of them explicitly refer to trying to avoid teaching science.
Those that do teach science are asked about positive and less positive experiences. Like Jane and Christian most of them focus their open reflections on students' 'reactions': 36 % of the positive experiences are backed by the teaching being relevant for the students, that it relates to students' everyday experiences, and that the students in this way were affected by the teaching – it was meaningful to them. 28 % refer to students being active having hands-on, while 32 % are specific about the students' learning through the activities. Some of the same types of reflections are seen when the teachers reflect on less positive experiences. 27 % argue about their own teaching not being good due to lack of hands-on experiences for the students, while 32 % refer to students' lack of learning. And 18 % refer to having problems with the science content themselves. When it comes to cooperation with colleagues around science, which proved to be quite important for Jane in particular, the answers from the teachers in the

cohort fall into three groups of nearly equal size. 28 % experience no cooperation around science at all, while 34 % refer to experiences from close cooperation with science colleagues, and the last 38 % note some, but not much, cooperation for example ordering materials together. The schools where cooperation in science teams is prioritized are the same schools which offer most induction and mentoring activities for new teachers.

The discussion of possibilities and challenges for continuing learning in practice is organized under two headlines: 1) learning from trying things out in practice and 2) learning through collegial interactions.
In relation to 1), both Christian and Jane emphasize incidents where they have experienced professional growth by trial and error in the domains of practice. They reflect on this (the personal domain) with the feed back loop from students' 'reactions' apparently being important (domain of consequence). Bakkenes et al (2010) reported that these kinds of experiments in practice are the most frequent learning experiences referred to by experienced teachers, and the results from the two cases here exemplify how the learning potential related to experimenting in practice and reflecting on those experiments is also huge for those two very different novice science teachers.
Eraut (2004) refers to four main types of work activity that regularly give rise to learning. These are 'tackling challenging tasks' and 'working with clients' as well as the two activities related to collegial interactions referred to below. Jane's experiences from challenging herself are a typical example. She is apparently supported in her self-efficacy by the experience of success in tackling a challenging task. This supports her to continue to be innovative. Christian who from the beginning had what appeared to be a higher level of self-efficacy related to teaching science emphasizes proactive experiments and learning from challenging tasks: things that do not work. For both Jane and Christian it is the 'reactions' from the students, their clients, that guide their interpretation of the experiments, and this is also the case for the teachers from the cohort. *But* I claim there is a challenge related to what kind of 'reactions' the teachers focus on, considering the importance current research puts on students being supported in

both manipulating materials and equipment *and* ideas in science. That for many Danish science teachers the activities are a goal in themselves rather than what the students might learn through the activities, is evident in this follow up study as it was in the first round of the cohort study (paper I).
In relation to 2) all Jane's cases involve collegial interactions around science, she refers both to a designated mentor, and to support on the spot from an available more experienced colleague, and also in Christian's school there is cooperation around science. However if there is no cooperation, as is apparently the case for a third of the teachers in the cohort, this learning possibility is not supported.

Eraut (2004) draws a distinction between more formal team-working towards a common outcome, and 'working alongside others' to become aware of different kinds of knowledge and expertise and gain some sense of colleagues' tacit knowledge. Jane's spontaneous examples and the cooperation Christian refers to when asked can best be characterized as informally getting ideas from colleagues, not as formal teacher learning communities with collaborative inquiries and discussions (McLaughlin and Talbert, 2006). Whether the lack of more formal collaboration in Danish schools can or should be addressed is beyond the scope of the present study, but the paper includes a quote from Eraut:

> "A group climate for learning has to be created, sustained and re-created at regular intervals" (Eraut, 2004, p.268)

The paper ends with perspectives looking forward both in relation to how to support teachers' continuing learning in and from practice, and how to examine and represent their experiences by means of the meaning-making model.

6. Overall discussion

The findings from each of the sub-studies are discussed in depth in the four papers. The focus of this section is the main findings *across* papers that refer to the overarching research questions:

- What kind of challenges and needs related to Danish UC-educated teachers' continuing development as science teachers can be identified?
- What characterizes Danish science teachers' meaning-making, when involved in facilitated collaborative inquiries sharing artifacts from practice?
- How can Danish science teachers' meaning-making be represented?

Though some papers contribute more than others to answering each of the overarching research questions as outlined in table 1 (section 4.2) most of the themes raised in the discussion below will refer to findings from *more* than one paper. The overarching research questions gave rise to pursuing themes across the various sub-studies, and the findings as I will discuss them here, were identified through an analytical process that identified similarities, differences, and interconnections between the findings across the four papers (Newby 2010). This analysis revealed how the main findings presented in each of the papers grew to be supported by perspectives from the other sub-studies, for example how findings from the cohort survey are better understood by adding in depth perspectives from the case-studies. Additionally, the analysis across papers renders possible a longitudinal perspective as some of the participants are followed in more than one paper.

The ten main findings are summarized in a continuing list below each section of the discussion.

6.1 Challenges and needs

Both internationally and in Denmark, the need for more science specific teacher development is widely acknowledged. But in Denmark, as noted in the introduction, little is known about the specific challenges and needs related to

science teachers' continuing professional development within the local context. Similarly there is a lack of studies on the suitability of the findings of international research for adaptation to Danish science teacher PD. There are, however, a few studies that have identified some of the shortfalls in the current approach to Danish science teacher PD. It has been highlighted, for instance, that novice primary Science & Technology teachers often feel insecure and therefore give up teaching Science & Technology after a few years, and that the teachers' feeling of confidence – their self-efficacy beliefs –apparently are influenced by environmental factors at their schools (Andersen et al., 2004, Ellebæk and Evans, 2005; Sørensen et al., 2005).

The research for the present thesis adds to these findings. In relation to the challenges and needs the discussion of these new contributions will be organized under three headings:

1) Orientation towards science teaching and learning
2) Confidence: variation between science teachers and how confidence might be supported
3) Availability of collegial support

6.1.1 Orientation towards science teaching and learning

In this section I will first outline how findings from the repeated cohort survey add new insight, and later I will include the findings from the case studies.
The cohort survey included both teachers with a Science & Technology specialization, and teachers specialized for the subjects taught in lower secondary: a full cohort of teachers with one of the science specializations educated at a large local teacher education institution (paper I and IV).
The first round of data included the graduating teachers' reflections on themselves as science teachers, and their argumentation about a range of short science teaching scenarios. Analysis of the graduating teachers' reflections revealed great variation, and significant differences between the teachers with the various science specializations - differences elaborated on below (and in paper I).

But the average picture is that the main way of arguing used in justification of science teaching is to refer to the students: Not to what is written in the curriculum and how you as a teacher can 'transmit' the authoritative science content to school students, but to how *they* can be activated and motivated (paper I).

So - it is quite typical that the arguments are student-centered, but the findings are not quite covered by simply a division into student-centered versus teacher-centered orientations as outlined in previous research (Anderson, 2007). In the discussion in paper I it is suggested that a two-dimensional landscape might better fit to illustrate the arguments from the novice Danish science teachers: they express student-centered beliefs, but focused on activity, not learning. Those findings are further supported by the findings from the second round of the cohort survey, where the same teachers are now in their second year in practice (paper IV). The main argument used to support an experience from science teaching as positive by the teachers is that the teaching showed to be applicable, meaningful and relevant for the school students, and so by affecting them. We know from research that a teacher's scaffolding of students' motivation to learn science can be quite important, and we know that such scaffolding for example can be done by drawing attention to why the content is worth learning, and how it can be used in the students' everyday life, and by supporting students in autonomously relating to and discussing their understanding of the science subject matter (e.g. Andersen and Nielsen, 2011 referred to in section 3.4.4 above). So seen from this perspective the findings can be a cause for optimism. But – and there is a but - challenges are identified in paper I and IV. Findings from both rounds of the cohort survey led to raising concern regarding the lack of emphasis on students' learning of science. When discussing this lack of emphasis the papers move beyond the science teachers' self-reports– and what they perceive as challenges themselves - and enter what is known about 'good' science teaching as a normative referent. Research indicates that a teacher's learning-centered focus other things being equal can be *the* important step to develop teaching (Borko, 2004). In relation to *science* teaching both recent policy papers and recommendations based on research emphasize the importance of expanding

the use of an inquiry-based approach (e.g. Rocard et al., 2007). How students' learning best can be supported through inquiry based science education is the theme of many discussions in that field of research, but there is as outlined in the theoretical background at least evidence of the importance of supporting students in manipulating *both* science equipment *and* ideas when working inquiry-based (Rocard et al., 2007; Lunetta at al., 2007). Manipulating ideas in science has in research been conceptualized as thinking science and talking science, and it is clear from the open reflections in the cohort survey that such considerations are not typical among young Danish science teachers: A student-centered focus is widespread, but not a learning-centered one.
There are a few examples in paper IV where the teachers back their arguments, about an experience from their teaching as being positive, with an example of how the students developed new understanding of the science content:

> "Dissecting pigs' eyes was an enormous eye-opener for many of the students and through the activity they gained a better understanding of how an eye is designed" (Quote translated from a novice teacher's reflection on a positive experience from teaching science - paper IV)

But there are no arguments - concerning the scenarios in the first round of the cohort survey or own teaching in second round – in which the focus is on specific teaching activities where the students are manipulating and discussing science concepts and ideas. Neither are there any examples where they as teachers refer to using specific approaches to examine their students' pre-conceptions and/or their developing understanding of the science content as the research recommends (e.g. Scott, Asoko and Leach, 2007; Hattie, 2009).

However there are reasons for cautious optimism when discussing the findings from the cohort survey against the findings from the case-study in paper II, where science teachers' meaning making during a PD project is examined. In the empirical research for this paper an understanding of the teachers' meaning-making related to the project – the collaborative discussions of artifacts from practice - was further pursued by analysis of their ideas about the teaching and

learning of science in general, beyond the context of the project. The data-based analysis of the teachers' utterances about teaching and learning science, renders plausible that three of the teachers change/develop their ideas about the teaching and learning of science over the year of the PD intervention in a way where they come to refer more to students' thinking, talking and learning in science. This was already a specific focus of the last teacher, a resource teacher, before the project. At the start of the school-based PD the novice teacher A for example referred frequently to her ideal of students' self-regulated hands-on activities in science and the tensions related to how to implement this ideal in her teaching: She found science a hard subject to teach and experienced problems in handling classroom management. In contrast to her focus on activities for their own sake at the start of the project the meaning-making map, representing her retrospective reflections, exemplifies how she grew to be aware of tools to examine students' ideas, and how by the end of the project she is highlighting the importance of students talking science to learn science, and of the teacher supporting them and structuring such discursive activities (fig. 3 in paper II).

The optimism *is* however cautious. As a last example I will summarize the experience of Jane (paper IV). A colleague helps her plan her first Science & Technology teaching and her reflections are consequently very much about hands-on science, copied from this colleague. There does not seem to be any transfer from her emphasis on students' collaborative dialogic activities in Geography, the area where she is specialized (more below). Science and Technology as a subject where students have to 'do and do and do' is apparently deeply founded also in the shared beliefs among the Danish science teachers – at least at her school - and this is the route she takes when starting to teach the subject in her second year in practice, not her PCK related to teaching Geography.

6.1.2 Confidence: variations between science teachers and how confidence might be supported

Another kind of belief refers to the teachers' confidence in themselves as science teachers, this can be described as self-efficacy beliefs (section 3.4.1 above).

I will start this section by summarizing the main findings related to teachers' confidence, and then I will move on to include some examples from the case studies related to teachers' confidence, their needs for support and their experiences of support, to further elucidate those findings.

The reflections from the teachers in the first round of the cohort survey indicate that low self-efficacy beliefs in particular in relation to the physics content are held by many of the graduating teachers with science specializations. But in this area there is significant *variation* among the teachers in the cohort - identified when analyzing their reflections. It is suggested in paper I that the teachers with a specialization in Physics and Chemistry appear more like university educated science specialists teaching in Danish upper-secondary school and it is hypothesized that they might have experienced success themselves in science in the school system, while many of the Science & Technology and Geography teachers might have negative experiences with science as learners.
Personal relational qualities and (subject specific) didactical competence are known to be important for teachers' ability to support student learning – maybe more than their subject matter knowledge (Nordenbo et al., 2008) - but concerning the UC-educated Danish science teachers, the emotional intensity in some teachers' reflections about lack of subject matter knowledge must however raise concern. At least it can be concluded that low self-efficacy beliefs as emphasized in previous research are important parameters to take into consideration when discussing science specific teacher development in Denmark, both pre-service and in-service.
To sum up: when seen in the context of the research outlined in this thesis there seem to be some *typical* challenges for Danish science teachers, for example the activity orientation mentioned above, while *significant variations* typify other challenges/needs, i.e. related to lack of confidence. Student teachers choosing the various science specializations at a UC differ a lot, and variations related to confidence can be expected in a typical science team at a local school. Both types of challenges need to be addressed during developmental activities.

The issue about confidence and how it can be supported is quite complex, as I will now discuss based on examples from the case-studies.

Teacher A and B, participating in the case study reported in paper II, both express what appears to be low efficacy beliefs related to the physics content. Teacher A is specialized in Science & Technology and teacher B in Geography, but she also teaches Science & Technology.
In paper I, reporting from the cohort, it is suggested that having low self-efficacy in the physics area might make the teachers from the cohort navigate around letting primary school students experiment with simple electrical circuits. This particular issue is exemplified by the experiences from Teacher B, so I will describe her experiences in a little more details, but just to sum up: both teachers A and B feel supported and seem to develop new confidence and agency as science teachers during the year with artifact supported collegial interactions.
At the start of the project teacher B had 3 years of experience in teaching Science & Technology, but she had not tried to teach simple electrical circuits. She had instead taken all her classes to a resource center outside the school to cover this part of the curriculum. During the project she was however supported in trying to teach her three 3rd grade classes simple electrical circuits, including examining their pre-conceptions and letting them manipulate with both science ideas – posing and discussing hypotheses - and with science equipment like small bulbs, batteries etc. Several artifacts, video and student drawings, from these trials were discussed in the PD workshops. Positive experiences from her classroom when trying the new practice are central in her meaning-making map. What was previously done at the resource center she now calls 'science as a show'. Furthermore she appreciates having tried to play a new role in the science team, where she states that she has been rather passive before. Building on these salient outcomes she is looking forward to continuing collegial interactions around science, and to enacting approaches alike the one used for teaching electrical circuits in other areas of Science & Technology.
So –a *lack of confidence both can influence and is influenced by ideas about teaching and learning science and the way experiences in practice are*

interpreted. The example indicates a possibility for supporting a teacher's confidence in her further experiments by, for example, facilitated (collaborative) inquiries into practice. The PD project influences how she thinks about science teaching and herself as a science teacher in the group of colleagues.

In relation to the role of a teacher as member of a group of science colleagues another case-study reveals the complexity of such relations: namely in the case of the teacher called Jane from paper III and IV also mentioned above in 6.1.1. Jane is specialized in Geography, but she also expressed an interest in teaching primary science during her last year of pre-service teacher education, albeit with some reservations to teaching Science & Technology due to her own knowledge background. The meaning-making map (translated in fig. 3 above) represents her experiences of teaching Science & Technology in her second year of practice. She had enough confidence to take up the challenge in the first place, but her insecurity made her turn to her colleague for help to get started. She in general feels supported by colleagues and inspired by participating in colleagues' teaching – an issue I will pursue in the next section – *but* she experiences discomfort by having a physics colleague in her classroom (co-teaching). She emphasizes that it is not a personal issue, she likes him, it is a fear of saying something wrong related to the science content which is intensified when co-teaching with him.
So - both these novice teachers express a lack of confidence in relation to the science content, they refer to support from colleagues, but also note that they feel insecure in the interplay with colleagues. Teacher B at the start of the study refers to the physics teachers as the real specialists and states that she does not think it is for her to contribute so much to the discussions in the science team, but she seems at the end of the project to be in a process of developing her confidence and agency in relation to contributing to the team looking forward.
The case of Jane further supports the understanding of the rather complex relation between confidence and the way a teacher becomes involved in and experiences benefit from interactions with colleagues. I do not have data to pursue the particular insecurity related to colleagues from physics, it might be connected to the significant variation between how teachers with various

specializations see themselves, but the results exemplify how *confidence in teaching science and willingness to share practice with science colleagues interact*.

Jane's case will be further discussed below seen in a longitudinal perspective (section 6.2.2). In the next section I will briefly focus on what the cohort-survey reveals about the possibility for getting support from colleagues.

6.1.3 Availability of collegial support

Support from colleagues seems to be important in relation to the individual teacher's confidence and agency. The cases of learning from practice Jane emphasizes imply various challenges and needs, but as a common thing all the examples exemplify her experiences of support from colleagues, whether that may be whoever is available or a formally designated mentor (paper IV). Support from the domain of collaboration is tightly connected to (new) enactments in the domain of practice for Jane, to her feeling of confidence (personal domain), and also influences her agency for continuing to try new approaches in her science teaching (domain of practice).

The possibilities for experiencing support from colleagues are problematized in paper IV, including data from a second round of the cohort-survey, and it is shown that the degree to which such opportunities are available at the schools differ very much. There does not seem to be an evenly distributed weight on teacher collaboration across the range of Danish schools. Some schools seem to have established teacher learning communities like those that are described in the literature (e.g. McLaughlin and Talbert, 2006), while collegial collaboration around science almost seems to be absent at other schools. This must raise concern among other things when seen together with the expressed insecurity related to teaching science, and the need for support, held by many science teachers. There is a lack of well-qualified science teachers for primary and lower secondary schools in Denmark (Følgegruppen, 2012), but still nearly 30 % of the local cohort do not teach science at all in the second year of practice, and furthermore 18 % of those that ended up teaching science express what appears to be low-self-efficacy beliefs. The between-schools variations indicate that the

influence from the change environment can be important: frames and traditions for collegial sharing and supporting each other have to be created and maintained at the school.

6.1.4 Main findings

The discussion above referring to the first overarching research question is summarized in the first 4 themes in the list of main findings.

1. An activity-orientation towards science-teaching seems to be widespread among Danish science teachers and with reference to the research base it might cause concern and be seen as a challenge when science teachers appear to be convinced of the value of hands-on activities without awareness of what science students are supposed to learn from the activities (paper I, II and IV).
2. The participating teachers in their reflections often focus on their students' reactions towards the science content, and their engagement and motivation, but a focus on students' learning is not so frequently exemplified in the teachers' spontaneous reflections. However the typical student-centered approach must be seen as providing possibilities. In the case-studies there are examples of teachers apparently being supported in their acknowledgement of students learning science by manipulating both science ideas and equipment (paper I, II, III, IV).
3. Confidence in themselves as science teachers, and in having sufficient subject matter knowledge, seems to be a quite influential factor in relation to how the Danish science teachers perceive science teaching, and how and if they see a future as a science teacher. Significant variations in this area are however found between teachers with various specializations. A related challenge is that nearly 30 % of a local cohort of science teachers do not teach science at all in their second year of practice reflecting and enhancing insecurity related to teaching science subject matter (paper I, II and IV).
4. The new teachers in the case studies emphasize how they pick up ideas from colleagues' practice and refer to the support offered by colleagues both informal by whoever is available, during intentional collaborative learning

activities, and by a formally designated mentor (paper II, III and IV). However there is a challenge since the support offered for (learning from) teacher cooperation differs widely between the participating teachers' schools (paper IV).

6.2 Danish science teachers' meaning-making of teaching practice and collaborative inquiries

The rationale behind the research reported in this thesis was inspired by the words of Feinam-Nemser (2001) that if we want schools to produce more powerful learning opportunities on the parts of students we have to offer more powerful learning opportunities to teachers. As stated there is a huge gap between what is known from research about how best to support teachers in their professional learning, and the learning opportunities teachers are typically offered. Above in section 6.1 some challenges and specific needs related to science specific teacher development in a Danish setting have been identified. Now I will move towards a discussion referring to the second overarching research question, looking further into Danish science teachers' meaning-making in relation to being facilitated in collaborative inquiries using artifacts from practice: PD activities designed according to the consensus criteria (e.g. Desimone, 2009). Part of this discussion will focus on the role of teachers' day-to-day experiences, as sharing those is a part of the mentioned consensus criteria, and potentially important in relation to sustainability and generative change. Teachers' meaning-making of day-to-day experiences is in particular addressed in paper IV.

I will start with a reference back to Dewey (1938/section 2 above). The great challenge when letting teachers' inquiries into their own practice be the center of PD must be to support the teachers in making their experiences, both the positive ones and the challenges they inevitably meet, worthwhile educationally. According to Dewey's thinking it is important to support the teachers in giving the experiences a worthwhile meaning in itself (the lateral aspect), but also to

support their agency to find ways to identify and deal with new problems as they arise in the future: the longitudinal aspect of an experience. This was the purpose when designing the interventions in paper II and III, but what did the pre-service and in-service teachers report as their perceived outcomes? How was the experience meaningful to them, how do they see their own development looking forward and what factors can be identified as important in the making of such experiences worthwhile educationally?

The teachers' perceived outcomes are discussed as part of their meaning-making in each of the case-studies, but I will take this discussion a little further, across the papers, using headings taken from Eraut (2004) who in his research into professionals' continuing learning claims a triangular relationship between *challenge*, *support* and *confidence*:

> "It is important to bear in mind that if there is neither a challenge nor sufficient support to encourage a person to seek out a response to a challenge, the confidence declines and with it motivation to learn" (Eraut, 2004, p.269).

The issue about confidence is discussed above. So the discussion here will be organized under the headings of support and challenge.

6.2.1 Support during PD experiences

In relation to support the teachers' meaning-making maps from the various case studies (paper II, III and IV) indicate a complex interplay between support from external domain and domain of collaboration, own trials in domain of practice and the consequences the teachers draw, and how they interpret their experiences. I will start with what the teachers from paper II see as outcomes: how they feel supported.

Each of the teachers from a local science team emphasize their personal experiences of feeling supported and inspired. This is consistent with results from previous research indicating that teacher development is related to individual

knowledge, beliefs and experiences (van Es and Sherin, 2008). However all the teachers in one way or another refer to insight into students' conceptual understanding, and to gaining insight and inspiration from colleagues' practice. They value the support from the external domain, the input of research based tools to examine students' ideas and look into their discussions in the classroom (students talking science)*, but* seeing how those tools can be used in practice in their colleagues' classrooms is the part of the experience of support they emphasize.

The student teachers in paper III also refer to concrete tools presented by the facilitator, but with a different focus. I will return to them later, for now I will stay with the teacher from paper II.

It is not only things that work well in colleagues' classrooms, the teachers refer to, like the examples of examining students pre-conceptions and guiding their discussions. Becoming aware that colleagues meet the same challenges as they do themselves, and getting ideas about handling issues that are not easy in any classroom situation seem to be an essential part of the support. The novice teacher A refers to realizing that they as colleagues all struggle with similar issues and this apparently supports her agency to cope with the challenges she meets herself.

Discussing science teaching and student learning with colleagues, and in particular getting the chance to actually see what happens in the colleagues' classroom (video), are highly valued by the teachers, both the novices and the more experienced. The issues about how students can be supported in manipulating science ideas (paper II) had, according to the local resource teacher, been discussed in the science team several times before, but the collaborative work with concrete artifacts seems to have concretized this, and to have created another kind of awareness of relevance in their *own* classroom: the artifact-mediated collegial interactions positively influenced an interest in developing their own teaching.

Supporting teachers in gaining awareness that elements of their own practice might be problematic (e.g. Bell and Gilbert, 1996; Tripp and Rich, 2012) is 'traditionally' seen as an important job of the external domain during PD. The

research reported in this thesis adds to this understanding by highlighting that *awareness of a need to change and agency to act on it can be supported both by the external and collaborative domains during artifact-mediated interactions. The two domains interact in relation to how the teachers feel supported (synergy): Support from peers is most about awareness and scrutiny related to concrete incidents, while support from the external domain includes new tools, theoretical lenses and ideas for transcending practices.*

The teachers however emphasize various kinds of outcomes and their meaning-making maps suggest a diversity of pathways. Examples of how these perceived outcomes noted by the individual teachers relate to tensions and challenges from the respective teachers' professional life are discussed in paper II. Some teachers take larger steps to change practice and cognition than others apparently following similar phases to those outlined in the Bell and Gilbert (1996) model. But all four teachers express interest in sharing experiences in the future: The perceived outcomes from renegotiating and reconstructing shared knowledge (domain of consequence) lead to new enactments in domain of collaboration. Furthermore they all experiment with new activities in their classrooms during the one-year project (domain of practice), and their meaning-making maps illustrate a *growing ability to interpret student's learning of concrete science subject matter* framed by these experiments (personal domain); a development of professional vision (Goodwin, 1994; van Es and Sherin, 2008) is indicated.
The various pathways teachers follow in their professional growth are discussed in earlier research (e.g. Clarke and Hollingsworth, 2002; van Es and Sherin, 2008), and above (6.1) it is concluded that some challenges and needs are more general in the Danish setting, while others are personal. Added to this it can be said that the iterative PD-design (paper II) seems to have rendered it possible to acknowledge the teachers' various needs, but also some of the common challenges.

The experiences and examples of support reported in paper II can be further understood if read along with the findings from papers III and IV, where four

teachers are followed, first as student teachers working on their bachelor project, and later for two of them as new science teachers.

When first comparing the findings from papers II and III it is clear that although there are several things alike the experiences of support from collaborative video-analysis reported by the student teachers have a different focus to those reported by the in-service teachers. The demands of being in a formal educational system, and the wish to master in the college context, to some degree overlay perceived outcomes related to mastering a classroom situation. This overlay, I have to admit, puzzled me during the first data analysis, though in retrospect I can see that it is a natural consequence of the situated character of learning outlined above in the theoretical background (section 2.2).

Still, the analysis of the workshop-dialogues, seen together with the interviews before and after workshops, revealed detailed examples where the student teachers supported each other to focus their attention on selective aspects of concrete incidents and classroom interactions - i.e. the students' learning (paper III). In the process of analyzing the video-clips from school practice they collaboratively reconstruct an understanding of dynamic features in the classroom-interactions, such as the line of discourse and communication: waiting time, triadic dialogue etc., which are known to be a great challenge in relation to novices' ability to observe (Star and Strickland, 2008). Besides referring to support from peers the student teachers also refer to being facilitated in a structured dialogue, and to a concrete analytical tool (external domain) that apparently helped them in the process. So - the findings support findings from paper II related to the complex interplay between support from the collaborative domain and the external domain.

Laursen (2007) talks about how Danish student teachers in general ask for tools to master the concrete challenges as a teacher instead of the more philosophical pedagogical theories. The student teachers in paper III also refer to this issue about t-theory versus T-theory (Korthagen, 2008, section 3.4.3 above). Their own reports of experiencing support through the use of the analytical tool refer more to the process of producing a bachelor project (the college context), than to interpreting the affordances of the situations in the classroom, but the analysis of

workshop dialogue exemplify their use of the analytical categories to gain a deeper insight into classroom-incidents and interactions: development of professional vision.

The two novice teachers A and B from paper II as mentioned also refer to support from concrete tools, however with a different perspective. For the student teachers the tool is used to analyze and make interpretations, mainly with a performance goal in mind, while the novice in-service teachers use tools as instruments to master concrete classroom situations. *But the need to have concrete tools to be able to see the patterns in student learning is the same*. At this point of explicitly emphasizing support from concrete tools the novices in the school based group (paper II) are apparently much alike the student teachers (paper III).

6.2.2 Being challenged – and making meaning

Getting back to the last headline from Eraut (2004) – *challenge* – the teachers from paper II feel supported to try new tools and approaches, but they also refer to being challenged during the interventions.

Teacher D in paper II for example refers to benefitting from overcoming her expressed anxiety of performance when experiencing being videotaped while using a tool inspired by concept cartoons (Keogh and Naylor, 1999) in her 8th grade class. She refers to new insights into her students' way of developing understanding of the science subject matter and to a new insight into how she as a teacher can frame their discussions. She, like several other teachers involved in the case studies, refers to the chance, rendered possible by video, to take a step back and reflect – not in, but - *on* practice (Schön, 1983), without having to respond immediately (Sherin and Han, 2004). Several of the participants phrase it like this: "*You focus on what actually happened not what you thought happened*". If a person can see on a video 'what actually happened' can be discussed philosophically – although in my opinion it is always an interpretation. These reflections are, however, quite important seen in the light of how hard it seems to be for a teacher to put aside what he immediately thinks happened, colored by his beliefs, and focus on alternative interpretations of what might have

happened in a given classroom interaction (van Es and Sherin, 2008). This does not come by itself –it is apparently a question of challenge.

Teacher D's meaning-making map (paper II, fig. 6) is furthermore one of the many examples of feed-back loops including the domain of consequence. She values students' new learning opportunities, and the challenge to be videotaped seems to give her confidence to use video-inquiries in the future as well as to continue developing ways to structure students' discussion without always needing to be in the center of discussion as a teacher.

Teacher B from paper II is also keen to continue to develop the students' learning opportunities rendered possible by the new teaching material *and* by the new role she tried to play in the science team.

Furthermore Jane, paper III, takes the risk to share video with peers from those situations where she feels most vulnerable in her teacher role. These include situations from school practice, which she felt had not been handled well, even before presenting the video in the workshops - situations where her 9th graders did not participate in class discussions and where she might be talking too much herself to make them discuss. In retrospective she highly appreciates the outcomes from the collaborative inquiry. The work has according to her been intense and different, compared to former tasks during teacher education (fig. 5, paper III). *Being challenged and going through a somewhat 'painful' process helped her find focus in her project.* But do those experiences also influence her professional work when leaving teacher education?

Transfer from pre-service teacher education to teaching practice is known to be complicated. As mentioned two teachers are followed over time from the beginning of their 4th year in teacher education to their second year in practice (paper III and paper IV). Jane is one of those, and I'll now look into her meaning-making from a longitudinal perspective.

Jane actually refers to the bachelor-inquiries in retrospective when asked about how she uses input from pre-service education now in her second year in practice. She reflects on how she uses structured cooperative activities informed by the experiences from *not* succeeding very well in making students discuss in

the videotaped teaching from the school practice. So building new enactment on salient outcomes can as emphasized by Clarke and Hollingsworth (2002) also be about negative experiences, and some of her insight seems to have 'survived the border to practice', though transfer to the new subject Science & Technology as mentioned was hard. Jane also – now in practice - refers to appreciating her own risk-taking. This is exemplified by her use of a science related incident discussed in the press, the tsunami at Fukishima, as a starting point in her Geography teaching acknowledging the students' many questions, though knowing that she prefers herself to be prepared 'to the teeth'. In her meaning-making map it is however not something learned from the collaborative video-analysis she refers to as making her keep on challenging herself. Nor it is something from pre-service teacher education in general. Instead it is support from her *present* colleagues, including her mentor. Her meaning-making at this stage has changed from being situated in the college context to being situated at the school. To what degree her willingness to keep on experimenting and to share practice with colleagues is supported by the experience from collaborative video analysis is therefore hard to say.

All the student teachers while still at college referred to the video-inquiry process as hard, but worth the effort. Challenge was for all four of them an element in their meaning-making process. I will now briefly look into the meaning-making of the other teacher followed longitudinally - Christian - and into the somewhat subtle balance between challenge and support. Christian has a high level background in science, and expresses a high level of confidence in his own competencies to understand the science subject matter and to teach it. He autonomously started his inquiries for the bachelor project and was highly motivated to get a chance to work with a 'real inquiry into practice': he refers to teacher education at the university college as, seen as a whole, lacking the culture of inquiring into and learning how to learn from practice. Christian however also expresses need for support in particular related to how to analyze the video, and in the peer-interactions around analyzing their respective videos it is exemplified how he starts to take notes and take into consideration the input from his peers,

and how he, with help from the analytical categories, subsequently talks himself into a way to understand a specific student-student interaction. In his meaning-making map (retrospective) it appears that he feels supported by the peers and by the analytical tool, and that he meta-reflects on how you learn as a teacher based on this. So for this very self-supporting student teacher there is *also* a fine-tuned balance where he feels supported and challenged to see new things and new angles. When meeting Christian two years later, he states that he uses the iterative way of learning from experience. This is not to claim a cause-effect relation, just to exemplify how the metacognitive part of his meaning-making is now a part of his way of coping as a practicing teacher.

To sum up - the work with video apparently increased several of the teachers' desires to change their teaching (Tripp and Rich, 2012) not just by means of support, but also by means of challenge. The teachers were inspired by the artifacts from the colleagues' classes and – seen together with input and facilitation from external domain - this challenged them to recognize a need to develop own teaching. But it is difficult to say how this challenge influences the teachers' cognition and actions in the long run based on the present longitudinal data. Contextual factors complicate the picture.
These examples are about how being challenged can help the teachers to get over thresholds in areas of tension. An additional, slightly differently perspective is however also indicated. According to Justi and van Driel (2006) teachers can benefit from being made aware of perspectives *distinct* from what they are used to. School based PD should, therefore, support the teachers *to move beyond what sometimes can turn out to be a limited local horizon of observation* in a team of teachers. The structured approach and the use of specific analytical tools were meant to support the teachers in seeing new things and pursuing new angles *and* the teachers actually emphasize being supported to "see what actually happened". Furthermore indications of development of professional vision are highlighted when going behind the teachers' self-reports and analyzing their workshop dialogue (paper III).

6.2.3 Main findings

The discussion referring to the second overarching research question is summed in the next themes on the continuing list of main findings.

5. Participating teachers when involved in the PD activities emphasize various kinds of support depending on concrete challenges they each experience in their professional work, and such challenges also guide their emphasis when referring to learning experiences from daily practice (paper II, III and IV).
6. However all the teachers involved in artifact-mediated interactions refer to gaining insight into students' conceptual understanding, and to insight and inspiration from colleagues' practice. And all participating teachers value experimenting in professional practice: purposefully trying out something new in practice combined with reflecting on student learning. This seems to be a driving force in their meaning-making also in relation to agency looking forward (paper II, III and IV).
7. Awareness of a need to change and agency to act on it seems to be supported both by external domain and collaborative domain during artifact-mediated interactions. Support from peers is most about awareness and scrutiny related to concrete incidents, while support from external domain includes new tools, theoretical lenses and ideas for transcending practices. So support from external domain might be needed to start and maintain local collaborative inquiries into practice (paper II and III).
8. An experience of salient outcomes related to students' learning opportunities seems to be important for the teachers continuing effort to qualify their classroom practice, *and* likewise participating teachers seem to be encouraged to continue developing collaboration with colleagues by the experience of personally gaining from these (paper II and III).
9. Both support and challenge seem important for change processes to be initiated and maintained. Confidence apparently can develop both based on experiencing success and support, and by challenge to keep on taking risks (paper II, III and IV).

6.3 The meaning-making model and the use of it

The discussion referring to the last overarching research question about how (Danish science) teachers' meaning-making can be analyzed and represented is about experiences from applying an adapted version of The Interconnected Model (Clarke and Hollingsworth, 2002).

I will focus on two main aspects in the discussion, 1) the adaption of the model with a new domain of collaboration and 2) the experiences from using the representation as meaning-making maps, in particular the fact that the unit of analysis has been the explicit utterances of the teachers.

6.3.1 Domain of collaboration as part of the meaning-making model

First a discussion of the relevance of the adapted model - in particular the inclusion of a new domain of collaboration. Adding more complexity to an esteemed model has to be substantiated by gaining an important deeper insight by using the model in this adaption, and I actually find, as I will exemplify below, that the new domain helped me identify what I see as highly important elements and detailed interplays in the participating teachers' meaning-making.

I have already discussed several examples of the complex and subtle interplays between confidence, support and challenge - interplays where peers seem to play a significant role. The way the teachers interpret their experiences from trials in the domain of practice, and input and support from the external domain, are in several cases influenced by collegial interactions in the domain of collaboration, and this interrelatedness is highlighted with the help of the adapted model. For example is confidence as a science teacher for teacher B growing through a facilitated mastery experience in the classroom and this is illustrated as interconnected with agency in collegial collaborations. Mutual responsibility for contributing to the development of science teaching at a school are known to be crucial (e.g. McLaughlin and Talbert, 2006), and therefore it is important that a tool meant to analyze and represent teachers' meaning-making related to a PD-experience 'capture' an example such as that of teacher B, where an experience of having a role to play together with colleagues is facilitated.

Furthermore there are several examples where the model helps to highlight how the challenge to begin to see a need to develop own practice can be initiated from interactions in the domain of collaboration, and how agency in relation to one's own continuing professional development can be shaped by individually - but *also* collaboratively - analyzing experiences and considering consequences for student learning. So important elements in relation to how teachers might acquire competences and agency for continuing learning in and from practice (Feinam-Nemser, 2001; Hiebert et al., 2007) is 'captured' by the adapted model. Last - but not least - new insight has grown in relation to *the interplay* between the domain of collaboration and the other domains by applying the adapted model, for example interplays with the domain of consequence. The inclusion of a domain of consequence in the interconnected model by Clarke and Hollingsworth (2002) was highlighted in section 3 above as one of the reasons to take this model as the starting point to develop a way to represent teachers' meaning-making. The important feed-back loops connected to teachers' interpretations of student learning when they try new approaches in the domain of practice emphasized by Guskey (1986), and by Clarke and Hollingsworth (2002), are in the present research supplemented with new findings suggesting similar feedback issues from experiences in the domain of collaboration. Teachers' appreciation of outcomes from collegial interactions in relation to their practice in the classroom might be the key to a continuing local effort to develop teaching collaboratively – an issue highlighted in the representation of mediations between the domains of consequence, practice *and* collaboration.

The interconnected Model in its original outline has proved to be well-suited for a research (and developmental) purpose in tracing trajectories of teachers' professional growth (section 3.3). Its adaption as a meaning making model lets it look into another level of such interconnections now designed to represent the teachers' meaning-making. Both when discussing meaning-making framed by a PD project with a design based on the consensus criteria, and when looking into teachers' meaning-making of day-to-day practice the collaborative domain has proven to be an essential element in the analytical model. The mentioned

interconnections would not have been visualized if seeing collegial interactions as part of the Change Environment surrounding all the domains, or if treating input and support from colleagues as part of the external domain like Witterholt et al. (2012). When introducing the adaption (section 3.4) I argue about important differences between interactions, trials etc. initiated by someone outside the normal day-to-day practice at a school and collaboration between the colleagues at the school. In a school-based project support and challenge from colleagues might be - by the individual teacher - experienced as commingled with that from an affiliated facilitator. Seen from a PD point of view it might actually be interpreted as a success if support for one's own development during a PD project is experienced comingled like that by the participants. But when it comes to the important issue of sustainability and potential for a generative development at a school after a PD project ends *separation in analysis is essential* to ensure that results from research (or evaluation) can be used formatively to inform future design of PD. The discussions above, with the help of the meaning-making model, suggest that support from peers is most about awareness and scrutiny related to concrete incidents, while support from external domain includes new tools, theoretical lenses and ideas for transcending practices. And the findings in paper III also imply a subtle balance in relation to supporting collaborative agency in a group of student teachers analyzing video-based practice by providing the tools and structured frames they need from external domain, but also acknowledging that their autonomy might be quite important in relation to their agency. Looking forward we as researchers and practitioners have to continually expand the understanding of how input and facilitation from an external domain can be balanced with the control of - and responsibility for PD in the local schools and the meaning-making model seems to have potential to highlight such interconnections.

6.3.2 The teachers' utterances as the unit of analysis

The second issue I will raise in this part of the discussion is connected to the concrete approach taken when using the adapted model in analysis and representation.

There are some minor differences in how the meaning-making maps are outlined due to the various contexts. The meaning-making maps in paper II and III represent teachers' utterances about *one* concrete shared experience with peers/colleagues, while the meaning-making maps in paper IV are connected to a range of cases of learning in practice that the teachers highlight themselves.
All the meaning-making maps have however taken the utterances of the teacher as the basic unit of analysis. In the various codebooks, for paper II included in the paper, and for papers III and IV in appendix 5, it is outlined how the representation as a meaning-making map is directly based on the interview-data. The perspective from the teacher is therefore acknowledged and the analysis could - as it is highlighted in the papers and above in section 4.4.1 - be done in a reliable way. This must be seen as a strength.
The meaning-making maps however represent the teachers' experiences as a snapshot – looking back and looking forward - though meaning-making is basically seen as a process. A teacher's longitudinal development process in macro perspective might be better visualized in representations like change sequences and growth networks (Clarke and Hollingsworth, 2002). While the strength of the meaning-making maps is visualizing in detail the interplays in individual teacher's meaning-making - *and* still rendering possible patterns to be pursued. As such the procedures developed along the present research built on the rich traditions to acknowledge individual teachers' experiences as the key to gaining insight into how best to support and facilitate PD - Dewey's understanding of enrichment of experience - but the research has contributed with (comparable) ways of aggregating this complex information into visual patterns.

One challenge identified in the theoretical background above is how to include the social negotiation of meaning in an analysis of an individual's meaning-making, this is (partly) solved by including the teachers' utterances about the collegial interactions. Another challenge is that teachers' knowledge is known to be complex and partly tacit, so important elements influencing teachers meaning-making may lie beyond the things expressed. Therefore data looking behind the

utterances from the individuals have been included in each sub-study: audiotaped workshop discussions, video from the teachers' classrooms, interviews focused on ideas about teaching and learning science, descriptions of the PD-interventions, and the ideas behind etc.
The meaning-making maps referring to the artifacts-mediated collegial interactions represent central findings in the papers, but none of the papers are *solely* based on the meaning-making maps, the domains have in various ways been 'opened up'. In paper II analysis focusing on the personal domain is included, and in Paper III analysis of social negotiation of meaning is included, contributing also to illustrate how the first analytical dilemma mentioned can be further acknowledged. Neither is paper IV *only* discussing the two novices self-reports about their learning from practice.

So to sum up on this last issue: Using the meaning-making maps as representations as in this thesis helps to highlight important interrelatedness in the teachers' meaning-making processes, but acknowledging teachers' self-reports as a unit of analysis may mean a need for additional perspectives.

6.3.3 Main findings

The discussion referring to the third overarching research question is summarized in the last theme for the continuing list of ten main findings:

10. Adapting the meaning making model with a domain of collaboration, and using it as a tool to analyze science teachers' meaning-making and represent it as meaning-making maps, has supported an insight into complex interplays and interrelations both in teachers' meaning-making processes in the frames of intentional professional learning activities (paper II and III) and concerning informal learning during professional practice (paper IV). But additional insight is obtained when combining the meaning-making maps with analysis also looking behind the teachers' self-reports.

7. Implications

Throughout the thesis I have referred to two interconnected epistemological branches namely science teachers learning and how best to support it during PD activities, and research oriented perspectives related to how to inquire into, represent and visualize science teachers' meaning-making. These perspectives will be included in this section's discussion of implications, but they will be organized by the meaning-making model as *a predictive tool* for considering implications for design of PD (fig. 5, question 1), and for future research into Danish science teachers' learning: their actions in the classroom (fig. 5, question 2) and their cognition (fig. 5, question 3). Implications in relation to the new domain of collaboration in the meaning-making model, and collegial interactions as part of teachers' learning are discussed above in section 6.3, and this domain is not considered separately here, but as an implicit perspective when looking from the three angles (fig. 5).

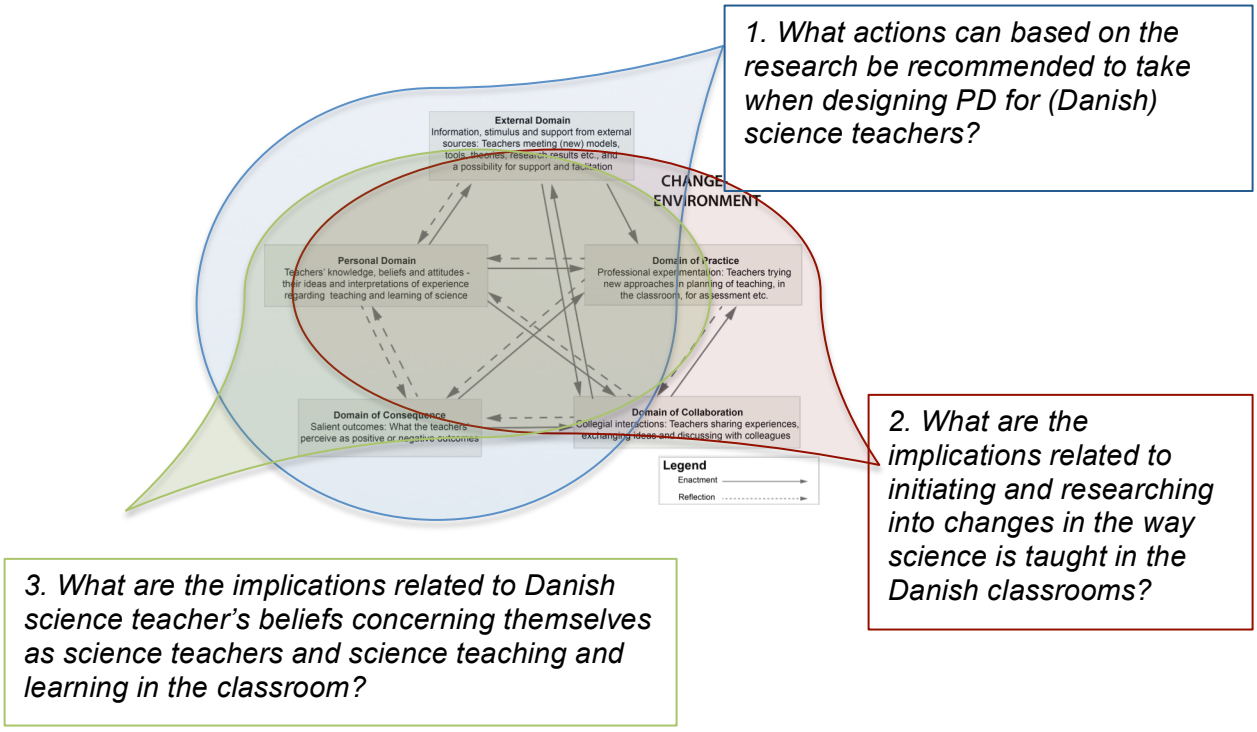

Fig 5: Three various angles taken when discussing implications

In the last part of the discussion above (section 6.3) the specific use of the meaning-making model as a tool in analyzing and representing teachers meaning-making, as it is done in the present thesis, was discussed. But originally The interconnected Model was suggested by Clarke and Hollingsworth (2002) to be used also as a predictive tool, and this is the inspiration to use the meaning-making model in a predictive way to consider implications *both* in relation to important elements when designing PD as it is mentioned for example by Clarke and Hollingsworth (2002) and van Driel and Beijaard (2003), and in relation to potential determent factors that have to be considered, when researching into teacher learning.

Starting first from the external domain, i.e. implications related to design of PD (Fig. 5 - 1), it can based on the research presented in this thesis be said, that if designing support projects for science-teachers (from external domain), it is important to consider *at least* how professional experimentation in own classroom and interactions with colleagues can be a part of the design. This is included in the consensus criteria at the start of the research, but the findings from this thesis have added new perspectives. The findings imply that support from the external domain during PD, the presentation of new tools, theoretical lenses and ideas for transcending practices can – in the best scenario - be merged with facilitating awareness and scrutiny related to concrete incidents between peers. Possibilities for developing local agency, both shared and by individual teachers, during school based PD have been highlighted, and the findings indicate how important it can be that PD supports teachers' experiences of mastering *both* in the classroom, and in collegial interactions to render possible their gradual experience of salient outcomes making them continue to be engaged in both: sustainability and generative change.
Further research is needed to expand the understanding of how input and facilitation from an external domain best can be balanced with the control of - and responsibility for PD at the local schools. More experiences from using representations like the meaning-making maps are needed, and this could be a central part of such an effort.

Next the present research has added new perspectives in relation to a particular *science* specific contextualization. Content focus is one of the consensus criteria, and it has been exemplified how a focus on ways to examine students' pre-conceptions make sense for in particular the novice teachers, and influence how they think about supporting students' learning of concrete science subject matter. Furthermore it is exemplified how a group of students teachers came to focus in detail on student learning and framing of classroom discourse with the help of an analytical tool developed based on the research base from science education. The novices need concrete tools to be able to see the patterns in student learning. More research is needed concerning how local science teachers can benefit from a range of such tools designed and based on the extensive research pool in the field of science education.

Looking forward the design of school based PD, and inquiries for student teachers, as artifact-mediated collegial interactions must also take into account the possibility for the teachers to engage in various ways and various tempi. As Dewey might have said it, when designing PD consider how different science teachers - and they surely differ a lot in the Danish setting according to the research in this thesis – can benefit both in relation to challenges in their present day-to-day practice and in relation to a growing confidence to manage future challenges. In the particular case of student teachers this is also about enhancing the likelihood of transfer.

Last but not least there is the local Danish perspective. The research has rendered probable that PD designed as artifact-mediated collegial interactions can influence science teachers' orientations in an area with particular local Danish challenges: the widespread activity related approach to science teaching and the lack of confidence held by many science teachers. The findings indicate the huge importance of supporting development of confidence in being a *science* teacher alongside understanding of science subject matter.

The particular Danish perspective can be the thread to consider perspectives seen from domain of practice (fig. 5 -2). The meaning- making model used as a predictive tool tells us that elements influencing a teacher's classroom practice – and potential change and development of it - include *at least* 1) their primary

education and PD experiences 2) their collaboration with colleagues 3) their knowledge and beliefs in relation to the science subject matter taught 4) what the teachers focus on, and see as salient, when interpreting their experiences, and 5) the change environment. Findings from the present thesis indicate that all the 5 elements potentially influence the way science is taught in Denmark, but in particular that an important research and development focus in a Danish context looking forward is the combination of hands on and minds on science in our primary and lower secondary science classrooms.
Future research might for example look into teachers' reflections and new enactments in their classrooms when taking up, from the external domain, the contemporary agenda of spreading and expanding inquiry based science education (IBSE, e.g. Rocard et al., 2007).

The last focus looking into implications is "the green perspective" (fig. 5 -3) highlighting the personal domain. In parts of the research for the present thesis further understanding of teachers' meaning-making was added by considering teacher beliefs about the teaching and learning of science and their confidence in themselves as science teachers. The findings have confirmed Danish science teachers' beliefs to be an important influencing factor. The tradition at the UCs with the integration of subject matter, pedagogy and internships could be a cause for optimism – it might be what facilitates the student-centered focus referred to above. The main challenge in Danish primary and lower secondary schools is not that teachers aim to transmit authoritative science content to students. However a tendency to 'activitymania' (e.g. Abell and McDonald, 2006) has been identified, and concerning knowledge and beliefs also the mentioned lack of confidence in own subject matter knowledge held by many science teachers. This calls for future research looking into Danish science teachers' meaning-making, and considering in particular knowledge categories. In the theoretical background (section 3) there are reference to various research projects using PCK as a construct, and there could be the opportunity to merging approaches from parts of the science specific PCK research with continuing use of the meaning-making model.

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Appendix 1

Paper I

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A cohort of novice Danish science teachers: Background in science and argumentation about science teaching

Abstract

A survey on science background and argumentation about science teaching was conducted on a local cohort of newly qualified Danish science teachers. The survey was administered before the novice teachers began their first jobs in primary and lower secondary schools and focused on their reflections on specific scenarios of science teaching and themselves as teachers in various science fields. Three areas of concern were identified: There was evidence of reflection upon and argumentation for the practice of science teaching being stundent centred, but many respondents showed a tendency to focus on students' activities as a goal in themselves, few considered what the students learned through the activities. Results furthermore suggest that the teachers' own assessment of their subject matter knowledge in the physics field may, for a large subgroup in the cohort, affect their approach to teaching science.

Introduction

A decline in young Europeans' interest in science during education and as a career has been widely discussed and recent policy documents recommend reforms in the approach to how science is taught in the school system (Rocard et al., 2007; Osborne and Dillon, 2008). Children's early experiences with science are crucial and teachers play a significant role in determining students' attitudes to school science and their subject choices, in fact teachers are claimed to be *the* single most important factor in relation to the quality of science education (Osborne, Simon and Collins, 2003). In Denmark, as in the other European nations, reforms in the teaching of science are discussed (e.g. Andersen, 2008), but there is a lack of local research that focuses on science teachers' backgrounds and approaches to science teaching. Much of the international research involves university trained secondary science teachers while teachers for Danish primary and lower secondary schools are trained in integrated university college (UC) programs. Students entering the Danish UC teacher education programs have been referred to as having a humanistic profile and concerns have been raised about graduation of too few teachers with a science specialization and that those who graduate have too little science subject matter knowledge (Andersen, 2008). A recent reform aiming to strengthen science led to raised admission requirements in the UC programs, with the immediate result that around 40 % fewer students specialized in science (Kristensen, 2009). There is already a lack of science teachers, so there is definitely a need for further reforms and for more knowledge about Danish UC trained science teachers. What is their background in science and their thinking about science teaching and themselves as science teachers?

Background

Science teachers' knowledge, beliefs and orientations

The work of science teachers is complex, dynamic and requires lots of decision making, as well as knowledge. Pedagogical Content Knowledge (PCK) has for the last 25 years been used as a construct to identify teachers' professional knowledge (e.g. Shulman, 1986, Abell 2007; Berry, Loughran and van Driel, 2008). PCK is highly content and context dependant. The aim of this study is a broad characterization of Danish science teachers' background, not to understand in depth the PCK of a single or a few teachers in reference to a specific science sub-area, as is the case with many studies in the ongoing PCK research. But the fundamental understanding is that learning to teach involves integrating and transforming different kinds of knowledge: Pedagogical Knowledge (PK), Subject Matter Knowledge (SMK) and Knowledge about Context.

It has been suggested that teachers' beliefs may be even more important than knowledge when making decisions in the classroom. Teachers may have similar knowledge, but teach in very different ways, and their beliefs can form a somewhat tacit, but still decisive conceptual map for instructional decision-making (Pajares, 1992). Later research has further investigated the complex relationship between teacher beliefs, which are mental, and their actions in the social arena, for example in relation to using inquiry in science teaching (Wallace and Kang, 2004). A simple causal relationship between beliefs and actions in the classroom cannot be assumed, but the importance of teacher beliefs in relation to their professional decision-making is widely acknowledged, and beliefs are considered a central component of PCK (e.g. Magnusson, Krajcik and Borko, 1999; Friedrichsen and Dana, 2005).

Teachers' approach to students' inquiries

Beliefs about the purposes and goals of teaching science at a particular grade level have been referred to as *orientations* towards science teaching and various orientations have been identified in literature i.e. process, conceptual change, activity-driven, discovery, project based, inquiry and guided inquiry (Magnusson et al., 1999). Research has revealed that prospective and practicing teachers often show a mix of orientations when arguing about various examples of science teaching, so it can be difficult to build up a precise profile for any *individual* teacher (Friedrichsen and Dana, 2003; 2005). But teachers' arguments and reflections about science teaching based in the interplay between their PK, SMK and personal beliefs and experiences might still show an *average* picture of a prevalent *student centred conception* of science teaching versus *a teacher centred conception* and an *activity driven orientation* versus *a transmission orientation* (Abell and McDonald, 2006; Abell, 2007). These orientations can be seen in a continuum where one extreme is the transmission orientation with the teacher as a dispenser of knowledge and students as passive receivers working with teacher specified activities, the other a student centred conception, with the extreme of seeing the teacher as a coach and facilitator and the student as a self-directed learner (Anderson, 2007). A tri-partition is used in other studies: A traditionalist teacher (transmission), a process oriented teacher, who focuses on scientific methods and experimental knowledge, and a constructivist teacher, who helps students construct knowledge (Tsai, 2002).

In contemporary research and policy papers the main challenge for reforming science in school is identified as the widespread use of the transmission orientation meaning that science teachers take a chalk and talk approach instead of a more inquiry-oriented approach (Rocard et al., 2007; Osborne and Dillon, 2008). But focusing only on this challenge might simplify the issue. Studies involving primary science teachers have highlighted a somewhat opposite problem, a purely activity-driven orientation with students spending a lot of time doing science, but little time thinking, talking, posing questions, or constructing explanations, with the goal of making science interesting, enjoyable and fun, but without much focus on what was learned (Abell and McDonald, 2006). Elementary teachers may be convinced of the value of hands-on-activities, but are not always able to develop science content from these exercises and may not even be aware of *what* science

students are supposed to learn from the activities (Levitt, 2002). Furthermore there appears to be a widely held lack of confidence among primary science teachers lodged in their own negative experiences as learners and a lack of confidence with their own SMK (Abell, Bryan and Andersson, 1998; Johnston and Ahtee, 2006). Meanwhile secondary Physics and Chemistry teachers seem more confident having typically experienced success themselves in their subject area in the existing educational environment (Tsai, 2002).

These results indicate that there might be decisive differences between the orientations toward science teaching and beliefs about yourself as a science teacher held by university educated secondary science teachers, who has been informants in many studies, and UC trained teachers, where less is known. This led to the following research questions:

Research Questions

1. What characterizes new Danish UC trained science teachers' science background?
2. How do new Danish UC trained science teachers reflect on themselves as science teachers?
3. How do new Danish UC trained science teachers reflect on science teaching?

Methods

Sample

Informants constitute the full local cohort of novice science teachers who graduated in June 2009 from a UC teacher education in Denmark (n=110). The training at the UC offers four science specializations: Biology, Physics & Chemistry, Geography and Science & Technology; the three first are identical to subjects taught in lower secondary, grade 7-9, while Science & Technology is integrated primary science, grade 1-6. The cohort in this study entered *before* the reform mentioned above and can be seen to represent a typical cohort of science teachers in the school system at the moment.

Data collection

Data was collected through a semi-structured web-based questionnaire, containing single item questions revealing background information, but with central questions seeking open ended, word based answers due to the exploratory character of the study. The questionnaire was administered at the end of training, but before the informants started their career as teachers. Data include answers about background in science, considerations about themselves as science teachers in various fields and reflections on a range of short *science teaching scenarios* (Friederichsen and Dana, 2003). Friedrichsen and Dana used science teaching scenarios as tools for helping teachers articulate their knowledge and beliefs during interviews. From their range of scenarios for elementary and middle school seven were chosen as central to the Danish curriculum. The scenarios, slightly refined to fit into a Danish context, are shown in table 1. The question following the scenarios was*: Is this an approach you would consider taking? It is very important that you substantiate your arguments and that you write what you think is positive/negative in the scenario compared to your conception of science teaching.*

Responses

The questionnaire was piloted and refined before final data collection. The response rate was 79%; 87 informants completed the full questionnaire. The division on the various specializations are shown in table 4 below. The gender division is 52 % male/48 % female: Physics & Chemistry 70/30, Biology 54/46, Geography 42/58 and Science & Technology 45/55. 'No replies' are distributed over all four specializations and are gender neutral.

Table 1: Science teaching scenarios used in the study. Reference to the Danish curriculum: Undervisningsministeriet, 2009.

Scenario	Which parts of this scenario might be expected to trigger in reflections?
1: Students in a 3rd grade Science & Technology class observe earthworms and generate questions and hypotheses about earthworms' behaviour based on their observations. Each group designs and carries out an experiment to test their hypotheses.	○ Phrasing pointing to inquiry based methods in science is used: generate questions, hypotheses, observation, experiment, test ○ Group work ○ Life science ○ Curriculum, Science & Technology: Ways of working and thinking in science: *formulate questions, pose hypotheses* and *animals and plants in the world near to you*
2: Students in a 9th grade Geography class work on a project about clean drinking water, which they are going to present in class. You as a teacher help with various materials, but the groups organize their own work.	○ Phrasing pointing to inquiry based methods in science is not used ○ Project work ○ Teacher as a facilitator ○ Earth science/environmental science ○ Curriculum, Geography, Biology *and* Physics & Chemistry: *describe the water cycle in nature*. Geography: *clean drinking water as a (global) resource*
3: You are teaching a unit about space and the solar system in a 6th grade Science & Technology class. The students read to the class about the various planets in the solar system and you take notes on the whiteboard in the class.	○ Phrasing pointing to inquiry based methods in science is not used ○ Whole class teaching ○ Teacher centred ○ Curriculum, Science & Technology: Ways of working and thinking in science: *reading in science, concepts/language* and the world far from you: *the solar system*
4: Students in an 8th grade Biology class choose a subject to explore according to their own interest. One student uses library books to research information on whales while another student sets up an investigation with experiments to study bread moulds.	○ Phrasing pointing to inquiry based methods in science: Explore ○ Students' individual work ○ Interest based ○ Life science ○ Curriculum, Biology: Ways of working and thinking in science: *design and explore* and *read and understand information*
5: Your students in 7th grade Physics & Chemistry are intrigued with a toy water rocket that a classmate has brought to school. As a group the students identify questions and experiments to explore how the rocket works. You help with the organisation and you investigate along with the students.	○ Phrasing pointing to inquiry based methods in science: identify questions, experiments, explore, investigate ○ Group work ○ Teacher as a co-investigator ○ Physical science ○ Curriculum, Physics & Chemistry: *describe and explain examples of energy-transfer in everyday and technical contexts,* ways of working and thinking in science: *formulate simple problems*
6: In a 2nd grade Science & Technology class you are presenting important information about separation of waste and recycling.	○ Phrasing pointing to inquiry based methods in science is not used ○ Teacher centred ○ Transmission ○ Environmental science ○ Curriculum, Science & Technology: *give examples about recycling and be able to sort waste*
7: In an electricity unit in 4th grade Science & Technology you give students batteries, bulbs and wires. You encourage the students to find all the possible ways to light the bulb.	○ Phrasing pointing to inquiry based methods in science is not used, but inquiry based methods are indicated ○ Teacher as facilitator when students explore ○ Physical science ○ Curriculum, Science & Technology: *Give examples of how we produce electricity, examine and describe everyday issues like electricity*

Table 2: Data-based categories and codes

Category	Description	Codes	Quotations
Teachers' argumentation about teaching in a certain science field			
Subject specialization	Argumentation is about their science specialization in teacher training	Positive because of specialization (PSS)	*Yes-this is my subject specialization*
		Negative because of lack of specialization (NSS)	*I do not have biology as a subject specialization*
Interest	Argumentation is about their personal interest in this field of science	Positive because of personal interest (PI)	*The best subject in the world! A subject where I am really burning.* *I find this subject interesting*
		Negative because of lack of personal interest (NI)	*This is a subject which since my own school time did not appeal to me*
Student Age	Argumentation is about the age of the children who have this subject in the school system	Positive because they would like to teach this age-group (PSA)	*I will look forward to teaching students of this age group*
		Negative because they would not like to teach this age-group (NSA)	*I would like to avoid teaching children below 6th grade*
Subject Matter Knowledge	Argumentation is about their own subject matter knowledge	Positive because they think they know something in this field of science (PSMK)	*I think I have a fair amount of knowledge to teach this subject*
		Negative because of lack of subject matter knowledge (NSMK)	*I know nothing about Physics.* *This is my weak side, and I would fail as a teacher if I had to teach it.*
Teachers' reflections and argumentation on the scenarios			
Students' motivation	The main argumentation surrounds whether students are motivated and interested or not.	Positive about students' motivation	*This is a really motivating approach*
		Doubtful if this is motivating for students	*This depend on whether the group is motivated by the work*
		Negative about students' motivation	*You could work with this in a much more interesting way*
Students' self-regulation	The main argumentation is about if – and to what degree the school students are able to regulate their own work	Positive about students' self-regulation	*They are going to find the results themselves* *9th grade know how to work on their own*
		Doubtful about students' self-regulation	*I would use such an approach to a certain degree being aware that some students have problem with self motivation*
		Negative about students' self-regulation	*It would be dangerous to take such a free approach*
Students' activity	The main argumentation is about students being active or passive	Positive because students are active	*It is good to have active students*
		Doubtful because students are too passive	*This I would consider doing but I would supplement with letting students sort real garbage*
		Negative because students are too passive	*Students are not active themselves in this case* *Students should not read about it, they have to go out and do*
Nature of Science	The main argumentation refer to students' experiments, hypotheses and scientific methods	Positive arguments	*Good with the scientific approach, that they have to pose a hypothesis*
		Doubtful arguments	*Students need an introduction so they know the concepts hypothesis and experiment*
		Negative arguments	*Students are too young to be able to pose a hypothesis*
Pedagogical theory	Arguments which refer to specific pedagogical theories, 'Bildung' or democracy in education	Positive arguments	*'Bildung' is a part of this* *A project oriented approach* *This is good democratic learning*
		Doubtful arguments	*I would take a project-oriented approach instead of group-work*
		Negative arguments	*I do not believe in this learning style*
Teachers' (lack of) subject matter knowledge	Arguments which refer to their own level of subject matter knowledge in this field of science	Positive	(no examples)
		Doubtful to consider this because of their lack of knowledge	*In principle I do not know much about this, but*
		Negative because of their lack of knowledge	*This sounds dangerous, I have no subject matter background to answer the question* *No I do not feel competent enough*

Analysis

Open answers were approached as qualitative data using methods from content analysis and open coding (Cohen, Manion and Morrison, 2007). The arguments about teaching a certain science field were coded as either positive or negative and according to the following four categories (table 2):

- Teachers' subject specialization
- Teachers' personal interest
- Students' age
- Teachers' subject matter knowledge

Through the same procedure of open coding six categories were developed to describe the teachers' reflections and argumentation on the scenarios (table 2):

- Students' motivation
- Students' self-regulation
- Students' activity
- Nature of Science (NoS): students' experiments and hypotheses and scientific methods
- Pedagogical theory of a general character (not from the field of science education)
- Teachers' subject matter knowledge

Each category was subdivided into positive, doubtful and negative. Coding was done separately by two researchers, inter coder reliability was more than 80% from the beginning and afterwards coding with incongruence was refined. There are examples of arguments referring to more than one category, but in the final coding all reflections could be coded in one of the categories in a reliable way referring to the *main* argumentation.

Acknowledging the diffuse character of teacher orientations the open coding of the scenarios was supplemented with two kinds of theory-informed coding (table 3).
Firstly, reflections were separated in process-oriented arguments, constructivist oriented arguments and arguments pointing to a traditionalist approach (Tsai, 2002). Through this analysis a category describing argumentation with *both* 'hands on' (process-oriented) and 'heads on' (constructivist) reference was separated, arguments which refer to inquiry as including the learners scientifically oriented questions, explanations, communication and justification (Abell and McDonald, 2006; Bybee, 2006).

Secondly, student-centred and teacher-centred arguments were identified to underpin a discussion of how reflections may be seen in reference to the continuum of orientations (Anderson, 2007). Student-centred reflections were sub-divided into arguments referring to students' learning and other student-centred arguments. Reflections referring to what students may learn through a certain teaching-approach were seen to differ from arguments for example being backed by something being a good idea while students were active. This subdivision acknowledges that a teacher's focus on how and what students learn is seen as decisive in contemporary research on teachers' professional development (e.g. Borko, 2004). In these two coding procedures some of the reflections were coded as 'other arguments' as it was not possible to place them in a particular category.

Table 3: Theory-informed codes

Codes		Description	Quotations
Teacher orientations I			
Process-oriented		Science is best taught by focusing on the processes of science or problem-solving procedures. Descriptors: teaching the scientific method; following problem-solving procedures; experiencing the processes of (self) discovery; working on the processes of verification (Tsai, 2002, p.774)	*It is motivating to take an...experimenting approach* *Good with the practical element and the scientific approach* *The scientific method is decisive and exemplary*
Constructivist		Science is best taught by helping students construct knowledge Descriptors: Helping students make interpretations; providing authentic experiences; interacting with students; encouraging discussion and cooperative learning; paying attention to students prior knowledge or misconceptions (Tsai, 2002, p.774)	*This is a good constructivist approach where students construct their knowledge* *It is important that students pose their own questions and starts their investigation from there* *I presume focus will be on students' pre-conceptions*
Traditionalist		Science is best taught by transferring knowledge from teacher to students (Tsai, 2002, p.774)	(no examples)
Integrated (hands on & heads on)		Integrated inquiry involves learners in the collaborative social practice of doing science and communicating about their doing and thinking (Abell and McDonald, 2006, p.250)	*students are using their hands and you can add theory while they are working and afterwards* *a good approach where the foundation is the student's experiments. The teacher of course has to follow up on students' experiences*
Teacher orientations II			
Teacher-centred		A focus on what the teacher does in the argumentation. The extreme is teacher as dispenser of knowledge and students as passive receivers (Anderson, 2007)	*I think it is important to tell student how the society works*
Student-centred	Students' learning	A focus on how the students learn in the argumentation. (an important part of teachers learning: e.g. Borko, 2004)	*Students learn by posing hypotheses and trying them out*
	Student centred	A focus on what the students do in the argumentation. The extreme is seeing students as self-directed learners (Anderson, 2007)	*Students at this level can organize such a work themselves*

Results

Science background

Based on information given about upper secondary education the cohort can be divided into two groups: High level background before teacher training or low level background. This is based upon *how much* science they took in upper secondary: A, B or C level, not on their marks (table 4).

In Danish upper secondary school (gymnasium) an A level is 3 years, a B level 2 years and a C level is 1 year of a particular subject. Combinations of levels of science subjects coded as high level are AA, AB, ACC, BBC or BCC. The % is based on the 87 teachers who completed the full questionnaire. The division across the four specializations is shown in numbers. Eleven of the teachers have opted for two science specializations in teacher training.

The result of making this rough division shows that 30% of the cohort had a high level background. 63 % of the teachers specializing in Physics & Chemistry in teacher training have a high level background, while the majority of the new teachers with Geography, Biology and Science & Technology specializations have only basic mandatory background in science from upper sec-

Table 4: Background in science from upper secondary school before beginning teacher training.

Specialization in teacher training → / **Background in science** ↓	**Physics & Chemistry** (21 teachers)	**Science & Technology** (19 teachers)	**Biology** (21 teachers)	**Geography** (37 teachers)	**Average**
High level science from secondary school	63 %	31 %	24 %	21 %	30 %
Low level science from secondary school	37 %	69 %	76 %	79 %	70 %

ondary school. This result is supported by the fact that nearly half of the informants specifically emphasize their humanistic background in an open category at the end of the questionnaire. 57% of the respondents reported their teacher identity attached to other areas than science. Physics & Chemistry teachers dominated when it came to identity as science teachers and also in relation to interest in science from their own school background. Some teachers, especially Biology teachers referred to interest in the nature/outdoor part of science in particular.
The gender division in high/low level background nearly follows the general gender division in the various specializations, for example 30 % of the ones who have high level background and Physics & Chemistry are female: so in each specific specialization high/low level background is gender neutral.

Reflections on themselves as science teachers

When asked if they want to teach in a certain science field all the teachers obviously expressed a preference to teach their own specialization, but more teachers were prepared to teach Science & Technology, Geography and Biology without having a specialization in contrast to Physics & Chemistry (table 5 a). 25.9 % state that they will say yes if asked to teach Physics & Chemistry, which is more or less the same percentage (24%) as those specialized, whereas 64.7 % would say no.

When analyzing what kind of argumentation the teachers use to back why they do or do not want to teach in the various fields, two kinds of representations are used in table 5. 67.3 % of the arguments for not wanting to teach Physics & Chemistry refer to lack of SMK (table 5 a). This is also the main category for Biology. Those without a specific background in Biology, but who would be prepared to teach it refer to personal interest (26.9 %). The same kinds of comments are made for Geography. Students' age is an issue especially when arguing about Science & Technology (primary science); 19.5 % are negative because of students' age, while 9.8 % are positive with reference to students' age. Table 5 c confirms significant difference between arguments used about wanting or not wanting to teach in the four science fields.

When looking into how teachers with various specializations argue on *all* fields summed (table 5 b) there is a partition in the cohort where arguments grounded in lack of SMK are expressed most by teachers with Geography (37.2 %) and Science & Technology (36.0 %), to a lesser degree by teachers with Biology (9.6 %) and only occasionally by teachers with a Physics & Chemistry specialization (2.3 %). There is significant difference between teachers with Physics & Chemistry versus Geography and Science & Technology, and also between teachers with Biology versus Science & Technology (table 5 c).

Table 5: Arguments used when reflecting on whether you want to teach various science subjects. P is positive arguments, N is negative arguments. SS=Subject Specialization, I=Interest, SA= Students Age, SMK=own Subject Matter Knowledge. All numbers are in %. Table 5 a: Results from asking all teachers what their answer would be if asked to teach the various science subjects and why they gave this answer. Table 5 b: Results from summing the kind of argumentation (overall) used by teachers with each of the four specializations. The three dominant types of argumentation are shown in various grade of shading in both tables. Table 5 c: Chi-square test, p<0.05 is highlighted.

Table 5 a	**Teach Physics & Chemistry?** (24 % specialized)			**Teach Biology?** (24 % specialized)			**Teach Geography?** (43 % specialized)			**Teach Science & Technology?** (22 % specialized)		
Arguments used ↓	Yes	Maybe	No	Yes	Maybe	No	Yes	Maybe	No	Yes	Maybe	No
	25.9%	8.2%	64.7%	32.5%	33.7%	30.1%	56.1%	26.8%	14.6%	53.1%	35.8%	11.1%
PSS	14.3 %			13.5 %			37.3 %			29.3 %		
PI	10.2 %			26.9 %			39.2 %			7.3 %		
PSA	-			-			-			9.8 %		
PSMK	-			7.7 %			3.9 %			24.4 %		
NSS	4.1 %			7.7 %			2.0 %			2.4 %		
NI	2.0 %			7.7 %			3.9 %			-		
NSA	2.0 %			1.9 %			2.0 %			19.5 %		
NSMK	67.3 %			34.6 %			11.8 %			7.3 %		
	100 %			100 %			100 %			100 %		

Table 5 b	Teachers with Physics & Chemistry specialization	Teachers with Biology specialization	Teachers with Geography specialization	Teachers with Science & Technology specialization
PSS	27.3	23.9	24.5	28.0
PI	41.0	34.8	17.0	10.0
PSA	2.3	4.3	3.2	4.0
PSMK	13.6	8.7	7.4	6.1
NSS	6.7	2.2	2.1	8.0
NI	4.5	4.3	3.2	2.0
NSA	2.3	2.2	5.3	6.1
NSMK	2.3	9.6	37.2	36.0
	100	100	100	100

Table 5 c			
Chi-square (df=7) From 5 a (*to teach*)		Chi-square (df=7) from 5 b (*teachers with*)	
P&C Bio	χ^2= 14.12 ρ=0.028	P&C Bio	χ^2= 9.996 ρ=0.996
P&C Geo	χ^2=33.34 ρ=0.000009	P&C Geo	χ^2= 15.525 ρ=0.029
P&C S&T	χ^2= 45.46 ρ=0.0000001	P&C S&T	χ^2= 20.044 ρ=0.005
Bio Geo	χ^2= 16.18 ρ=0.013	Bio Geo	χ^2=10.056 ρ=0.185
Bio S&T	χ^2= 36.99 ρ=0.000005	Bio S&T	χ^2= 14.482 ρ=0.043
Geo S&T	χ^2= 30.96 ρ=0.00006	Geo S&T	χ^2= 3.173 ρ=0.868

The teachers with Physics & Chemistry seem to feel more confident in teaching life and earth science as well. If they argue for not wanting to do it, their arguments are not about lack of SMK like examples from other teachers when referring to Physics & Chemistry:

"How could I possibly teach something I do not understand at all myself."

or about Science & Technology:

"I am not good in the physics part."

When teachers with Physics & Chemistry do not argue about lack of SMK it might be due to their higher background from upper secondary (above), *but* Biology teachers do *not* have a similar background from upper secondary.

Reflections on science teaching

Results from analyzing teachers' reflections and arguments on the seven scenarios are shown in table 6. The results about arguments used most frequently, by *all* teachers for *all* seven scenarios are highlighted in the bottom row.

16 % of the argumentation is about students' motivation:

"A problem based approach is an excellent motivating factor."

and 18 % about their self-regulation:

Table 6: Teachers' reflections on the seven scenarios. The coding of the type of main argumentation showing columns with the six categories, each category sub-divided into Positive (P), Doubtful (D) or Negative (S) and in a separate row summed % of argumentation in this category. In the last column the average is shown for each scenario. The most frequent argumentation is bold. In the last row the average for all teachers on all scenarios is shown. All numbers are in %.

Scenarios	P positive D doubtful N negative	Motivation	Self regulation	Activity	Pedagogy	Nature of Science	Subject Matter Knowledge	Average
Scen. 1 Earthworms	P D N	7.8 - -	4.3 - 4.3	15.5 - -	7.3 2.6 -	44.9 9.0 1.8	- - 2.5	**P 79.8** D 11.6 N 8.6
	Summed	7.8	8.6	15.5	9.9	**55.7**	2.5	100
Scen. 2 Drinking water	P D N	6.6 1.7 -	47.2 15.7 5.0	4.3 - -	16.1 - 1.7	- 1.7 -	- - -	**P 74.2** D 29.1 N 6.7
	Summed	8.3	**67.9**	4.3	17.8	1.7	-	100
Scen. 3 Solar system	P D N	- - 23.4	- - 2.5	- - 39.1	5.3 3.1 18.9	1.5 1.5 4.3	- - -	P 6.8 D 4.6 **N 88.6**
	Summed	23.4	2.5	**39.1**	28.1	6.9	-	100
Scen. 4 Biology project	P D N	11.5 2.6 -	32.4 11.7 -	- - -	14.3 19.6 1.8	1.8 3.5 1.8	- - -	**P 59.0** D 37.4 N 3.6
	Summed	13.1	**44.1**	-	35.7	7.1	-	100
Scen. 5 Water rocket	P D N	53.4 2.4 -	2.4 2.4 -	1.7 - -	13.6 3.9 -	10.5 - -	- 1.9 7.8	**P 81.6** D 10.6 N 7.8
	Summed	**55.8**	4.8	1.7	17.5	10.5	9.7	100
Scen. 6 Recycling	P D N	- - -	- - -	- 12.7 19.6	53.6 8.9 3.6	- - -	- 1.6 -	**P 53.6** D 23.2 N 23.2
	Summed	-	-	32.3	**66.1**	-	1.6	100
Scen. 7 Light the bulb	P D N	10.2 - -	3.7 0.9 -	41.1 - -	5.5 0.9 -	10.4 5.8 1.9	- - 19.3	**P 71.2** D 7.6 N 21.2
	Summed	10.2	4.6	**41.1**	6.7	18.1	19.3	100
All teachers on all scenarios	P+D+N	**16**	**18**	**22**	**25**	**14**	**5**	**100**

"Students at this level can organize such a work themselves."

Students' level of activity is used as a warrant in 22 % of the argumentation. Positive arguments in this category are about active school students whereas negative and doubtful arguments are about students being too passive. Main argumentation referring to NoS:

"Posing hypothesis and trying them out."

comprises 14 %.

Table 7 and 8 show analyses for all arguments on all scenarios coded according to table 3.

Table 7: Type of argumentation, all teachers on all scenarios, divided in teacher-centred versus student-centred argumentation.

Teacher-centred	Student-centred		Other (cannot be categorized)
	Students' learning	Other student-centred	
29 %	9 %	45 %	17 %

Table 8: Type of reflections, all teachers on all scenarios

Process-oriented	Constructivist	Traditionalist	Integrated (hands on + heads on)	Other (can not be categorized)
21 %	41 %	0 %	5 %	33 %

More than half the arguments indicate a student-centred focus (table 7), but positive arguments about students' activity or negative arguments about passive students are not often associated with students' learning or lack of learning, only 9 %.

In table 8 referring to Tsai (2002) the main part of the argumentation, 41 %, indicates a constructivist view either explicit:

> *"This is a good constructivist approach where students construct their knowledge."*

or implicit according to the descriptors in the codebook in table 3:

> *"The special focus on posing questions can be used to clear up the students' prior knowledge and their pre-conceptions and support the students."*

29 % is coded as process-oriented. This sort of argumentation focuses on scientific methods and problem solving. A small fraction of the process-oriented arguments explicitly mention what they call *the* scientific method, emphasizing one particular specific scientific method, one of the frequently mentioned misconceptions in the area of NoS. These teachers all have a Physics & Chemistry specialization and a high level background. 5 % of the arguments indicate an integrated approach to inquiry, where there is a reference to hands on as well as heads on:

> *"Students are using their hands and you can add theory while they are working and afterwards."*
>
> *"A good approach where the foundation is the student's experiments. The teacher of course has to follow up on students' experiences."*

Students formulating explanations from evidence, as in the contemporary understanding of integrated inquiry (Bybee, 2006; Abell and McDonald, 2006), is not mentioned but still, these arguments are different from arguments just referring to hands on activities.
There were no reflections indicating a transmission orientation (Tsai, 2002).

When looking further into the kind of argumentation used for the separate scenarios (table 6) in the case of scenario 1 (*students observe earthworms, generate questions and design an experiment*) 55.7 % of the teachers refer to NoS in their argumentation. This could be expected, while words like observation, hypothesis and experiment are explicitly used in the phrasing of the scenario. It might be more interesting that 32 % of the arguments refer to active, motivated, self-regulated students *without* mentioning hypothesis, inquiry or scientific methods. When comparing with scenario 7 *(find possible ways to light the bulb),* where such phrasing is not as explicit, a smaller percentage of the arguments, 18.1 %, are categorized as referring to NoS. This scenario plus the earthworm scenario are where a small group of teachers with a specialization in Physics & Chemistry refer to *the* scientific method.

The bulb scenario and another referring to physics SMK (scenario 5: *the water toy rocket)* are where the reflections about lack of own SMK are concentrated, contrary to the scenarios referring to life science or earth science. 19.3 % of the teachers spontaneously refer to a lack of own SMK as a limitation when arguing about the bulb scenario. Except for the references to a lack of SMK, the argumentation about the water toy rocket scenario is mainly positive (81.6 %). Many positive reflections is about the teacher acknowledging the students' ideas, but the fact that the scenario refers to physics subject matter urges some of the informants to make certain reservations:

> *"This is a clear example of teaching starting where the students are interested, if only it was not about Physics & Chemistry!"*

In argumentation about scenarios 2 and 4 reference to students' self-regulation is frequently used (67.9 % /44.1 %). Most teachers are positive, but there are doubtful and negative arguments questioning whether students can handle the free approach. There are not many NoS arguments regarding these two scenarios, but some teachers argue that all students ought to include some kind of experiment in their projects.
In the scenario about recycling many arguments are about this being an important issue:

"Bildung in an early age."
"It is important to take care of nature."
"Bildung to global citizenship."

These arguments are coded as pedagogical arguments. This kind of argumentation refers to the so-called 'German didaktik tradition' (Duit, Niedderer and Schecker, 2007; Westbury, Hopmann and Riquarts, 2000). 'Bildung' stands for the formation of the learner as a whole person, and in this tradition content chosen must represent some general ideas, for example what the German educator Wolfgang Klafki calls epochal key problems: *the general as that which concerns us all in our epoch* (Westbury, Hopmann and Riquarts, 2000 p.104). 32.3 % of the reflections on this scenario are about the need for students' activity, not just the teacher telling, these arguments contribute to the doubtful and negative statements about the scenario. The reflections include concrete ideas for activities to teach recycling not just by telling.
The scenario gaining most negative responses (88.6 %) is the one about the solar system. 39.1 % back the argumentation on the fact that the students are not active, 23.4 % felt it was not motivating and 18.9 % pedagogical arguments suggesting other pedagogical approaches:

"This I would make project-oriented and it could be a cooperative project with arts."

To sum up, particular types of arguments are used more frequently in the argumentation about each of the scenarios, when it comes to whether the teachers are dominantly positive or negative, and the kind of argumentation used to back it. This confirms prior findings, that a single label cannot describe teachers' orientations (Friedrichsen and Dana, 2005). The 7 scenarios trigger in various ways the teachers' reflections, but there is an average picture of the main part of the argumentation being student-centred and about student activity, self-regulation and motivation. The lack of (positive) reference to own SMK, and what can be seen as relatively few arguments referring to NoS even when central in the phrasing of some scenarios is also interesting. The latter is further elucidated below where reflections are separated according to various specializations.

Variation between the specializations

The summed argumentation about scenarios is divided across the four specializations in table 9.

Table 9: Arguments used by the teachers in reflections on scenarios (summed) divided on specialization in teacher training. All numbers %. Average is calculated based on number of teachers with each specialization. Some results referred to are highlighted.

	Specialization ↓	Motivation	Self regulation	Activity	Pedagogy	Nature of Science	Subject Matter Knowledge	
Summed argumentation	P & C	19.4	19.4	16.1	24.7	20.4	0	100
	Bio	17.5	21.4	16.6	27.2	13.6	3.9	100
	Geo	15.9	18.1	21.8	25.4	11.3	7.5	100
	S & T	13.1	15.0	23.6	24.8	19.6	3.9	100

A Chi-square test shows significant difference in argumentation between Geography and Physics & Chemistry teachers (χ^2=11.71, df=5, ρ=0.038). Physics & Chemistry teachers never use the argument about lack of SMK and are more likely to ground their arguments in the field of NoS. The average above in table 6 is relatively much influenced by Geography teachers who comprise nearly double the number of Physics teachers in the cohort. Science & Technology teachers, besides having most reflections about activity, also seem to back their arguments in NoS more than Geography and Biology teachers. This is not significant (Geo/S&T: χ^2=10.06, df=5, ρ=0.071) but when dividing the analysis according to the Tsai categories (table 8) there is a significant difference between Geography and Science & Technology teachers (χ^2=13.79, df=3, ρ=0.003) and Geography and Physics & Chemistry teachers (χ^2=17.28 , df=3, ρ=0.0006). Physics & Chemistry and Science & Technology teachers use more process-oriented argumentation than Geography and Biology teachers (P & C: 41 %, S & T: 30 %, Bio: 27 %, Geo: 18 %).

Discussion and conclusions

The discussion will be organized starting with exploring the significance and going behind the results referring to the science teachers' background and reflections on themselves as science teachers and on science teaching, and from there move on to the great variation found in the cohort.

Science background and reflections on themselves as science teachers

The indications of *low efficacy beliefs* in many of the reflections may raise some concern (Bandura, 1997). Research suggests that SMK is an issue for being an effective science teacher, not more important for teacher effectiveness than knowledge of how to teach (e.g. Darling-Hammond and Youngs, 2002), but low self-efficacy might very well affect the way the teachers will teach primary science, and in the Danish schools a teacher is normally 'counted as' trained to teach primary science with *any* of the science specializations (the full cohort). Having low self-efficacy in the physics area they might try to navigate around letting primary school students experiment with simple electrical circuits, as made probably by some of the teachers' comments about the bulb scenario:

> *"This sounds dangerous."*
> *"I have no subject matter background to answer the question."*
> *"No I do not feel competent enough."*

A lack of belief in their own SMK in physics might therefore hinder these teachers in teaching primary science as it is described in the Danish curriculum; their PCK for teaching simple electrical circuits is affected. Furthermore low efficacy-beliefs about own SMK in the physics and chemistry area might potentially affect biology and geography teachers when teaching in some parts of *their own* specialisation, as indicated when a biology teacher states:

> *"My limitation in biology is connected to my lack of knowledge in the chemistry area."*

Variance in background in science before starting teacher training may play a role in the results showing that teachers with Physics & Chemistry are more prepared to teach out of specialization. *But* Biology and Physics & Chemistry teachers are the ones most alike in their way of arguing about teaching out of specialization (table 5 c) though they differ in background level, and when looking at the reflections on the scenarios it is notable that *none* of the teachers with Physics & Chemistry use NSMK arguments, *independent of background level, gender etc*. A clear conclusion on reasons for this pattern goes beyond the empirical background in this study, but self-efficacy as stated seem to be an issue, beside science background. The teachers' low efficacy beliefs attached to physics might go back to how they themselves have experienced different content fields when at school. Negative experiences as learners can result in negative attitudes and apprehension about especially physics teaching, as it is seen in other studies (Abell et al, 1998; Johnston and Ahtee, 2006). Such deeply founded (tacit) experiences might affect student teachers' choice of specialization, so those having negative experiences as learners do not choose 'hard science' (Physics

& Chemistry and apparently to some degree also Biology). This might also explain the need to explicitly specify, even when not being asked (in an open category) that they have a humanistic background.

Reflections on science teaching

The physics content is clearly seen as especially complicated and difficult, and earth science as easier to cope with. The nature of physics is according to Duit et al. (2007) partly the reason for this being experienced as difficult, counterintuitive and incomprehensible by learners. Physics thinking does not originate from observation of the world around us, but from the reconstruction of this world under the assumption of theoretical principles, this means a very high level of abstraction and idealization (Duit et al, 2007, p.605). In Duit et al. (2007) it is mentioned that especially girls perceive physics as complicated. Gender has only briefly been included in the discussion in this paper, while results have shown no clear differences. Female teachers are overrepresented among those that refer to lack of SMK, when reasoning about the scenarios; 40 % male/60 % female, compared to 52/48 in the cohort, but if taking teachers with Physics and Chemistry out, since none of them use this argument (male or female), it is nearly gender neutral as there are more male Physics and Chemistry specialists. Male teachers with Geography, Biology or Science & Technology use argumentation indicating low efficacy beliefs as much as female teachers, and those female teachers that have Physics and Chemistry seem to argue more like male teacher with this specializations than as female teachers with for example Geography.

To sum up: The teachers in this cohort are not alone in having experiences of physics as a complicated science field, but a large subgroup seems to have *so* low confidence in this area that it affects how they see scenarios of science teaching, even scenarios related to relatively simple physics subject matter.

In relation to orientations towards science teaching none of the novice Danish science teachers showed indications of a traditionalist transmission orientation in their reflections on the scenarios (Tsai, 2002; Anderson 2007). It is however important that what is seen is the newly qualified teachers' ideals (*what they say they want to do*), what they actually are going to do in complex and sometimes confusing classroom situations is beyond the scope of the study. Examples where teachers use a transmission approach though expressing a constructivist orientation are well known. Nevertheless the results confirm the hypothesis that the activity-driven extreme (Abell et al, 1998) is prevalent. In many of the reflections activities are assumed to make science interesting and motivating, with reference to what the students can *do*, not so often how the students *learn*; activities is seen as 'the sugar on the pill' (Zahorik, 1996). Science activities surely *are* important ingredients in contemporary science teaching, but talking science and using science related argumentation is *as* important *and* so is a specific focus on students learning of science, which is only seen to a small degree (Bybee, 2006, Abell and Mc Donald, 2006). In Andersons' continuum of orientations the average novice Danish science teacher is placed as having a student-centred conception, seeing the student as self-directed learner. This widespread tendency to consider students' motivation can in many ways be seen as a strength in this UC-cohort compared to the teacher-centred thinking about transmission of science seen in some research (e.g. Tsai, 2002), but the continuum of orientations might be better illustrated as a two- dimensional landscape where most Danish UC educated science teachers express student-centred beliefs, but focused on activity not learning.

To sum up: The results point to at least three important issues of concern when looking at the cohort in average: 1) the newly qualified teachers' reference to science subject matter, especially physics, 2) their expression of student-centred beliefs with hands on activities being *the* issue and 3) their (lack of) considerations about students learning.

Variation in the cohort

When discussing confidence as science teacher in as well physical science as earth and life science expressed indirectly in the readiness to teach out of specialization, rather clear patterns were found as stated above. Physics & Chemistry teachers in the cohort seem to be more alike the secondary teachers in the study of Tsai (2002) in the sense of feeling confident, while Geography and Science & Technology teachers are more alike the primary teachers referred to in other studies (e.g. Abell and McDonald, 2006).

To supplement these conclusions another way to illustrate the *great variation* found in the cohort is to use the thinking from Max Weber's ideal types: *idea-constructs* that can help put the chaos of social reality in order (Weber, 1997) to highlight some *extremes*:

- Teachers who have a high level background in science and identify themselves as *science teachers in particular*. They have mathematics as another specialization beside Physics and Chemistry. They state that their interest developed from their own school experiences and some explicitly express that they love physics. They mainly express a process orientation in the way they argue and some use the expression *the* scientific method.
- Teachers with a low level background in science, who typically use arguments about students' activities being *the* important thing in *primary science*, including process-oriented arguments with phrasings about students posing hypotheses etc. They might have chosen Science & Technology specialization, not so much to become a science teacher, but to be able to include science perspectives when working with primary school students and they emphasize activities especially useful in primary science teaching.
- Teachers with a low level background in science and an explicitly formulated *humanistic profile* as the background for choosing Geography. They do not *at all* see their teacher identity attached to being a science teacher and several express a lack of SMK in the physics area. They often use constructivist-oriented arguments, emphasize "bildung" in their argumentation and refer to students' motivation as backing in argumentation about self-regulated activities. They might have chosen Geography as a specialization based on interest in cultural and global issues.
- Teachers who value *outdoor activity* for themselves and as a pedagogical approach. Students' self-regulated activities are seen as important and many have sports as another specialization beside Biology. They might always have been interested in science, but not necessarily science in the school system, rather an interest in the 'nature part' of Biology, not 'the chemical part'.

It must once again be emphasized that such ideal-types are used to illustrate *the wide range* of science background and expressed beliefs about teaching and learning science. Many teachers in the cohort are somewhere in between these extremes.

Limitations, implications and perspectives

The present study has its limitations. The nature of the study has been highly explorative due to absence of existing research about Danish UC educated science teachers. In retrospect it might have been helpful to use additional cases/scenarios and qualitative in depth studies may be better suited to study teachers' beliefs and orientations. But regarding the aim to get an average picture, the findings have significant implications both in relation to pre-service and in-service training.

There is no easy way to meet the challenges concerning relatively low background in science and negative beliefs about own SMK, which can create a tension in the development of PCK. Raising admission requirements as in the reforms mentioned above is a reasonable political step, but there might be other ways. We might be able to support development of confidence alongside understanding of subject matter and development of (science specific) pedagogical skills building upon the competences and strengths shown for example in the basic student-centred thinking about teaching and learning science. A clearer understanding of the great variation among science

teachers, and their associated needs, might also be used to understand how different student teachers and novice teachers might have different learning trajectories in developing PCK for science teaching.

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Appendix 2

Paper II

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Science Teachers' Meaning-Making When Involved in a School-Based Professional Development Project

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Abstract A group of teachers' meaning-making when they are collaboratively analyzing artifacts from practice in local science classrooms in a school-based professional development (PD) project is examined through repeated interviews and represented as meaning-making maps. The interpretation of the teachers' meaning-making includes both their reference to outcomes from the project and their expressed ideas about teaching and learning of science. All four teachers refer to experiences from experimenting in their classrooms and interpret the collected artifacts in relation to students' learning. Furthermore, they all felt encouraged to continue collaboration around science. During the interviews, the teachers emphasize various elements apparently connected to concrete challenges they each experience in their professional work. Implications in relation to the design of PD are discussed.

Keywords Professional development · Teacher meaning-making · In-service teacher education · Teacher learning · Artifacts from practice

Introduction

It is acknowledged internationally among practitioners and in research that we need to develop science teaching and that science teachers are the key to accomplishing this task (e.g. Rocard et al. 2007; Osborne et al. 2003). Therefore, professional development (PD) activities for teachers have the potential to play a crucial role. In particular, it is important to support the teachers in continually developing their

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competence to learn in and from practice, that is, to analyze teaching in terms of its effects on students learning (Feinam-Nemser 2001; Borko 2004).

In Denmark, various initiatives have been undertaken in recent years to develop science teaching. For example, some science teachers have been offered the opportunity to take an in-service course in science education leading to a diploma (bachelor level). This is to supplement their science specialization from pre-service education and it also means that they can act as science resource teachers within their schools. However, most science teachers have little opportunity for PD; typically, they are offered short, out-of-school courses that are detached from practice, and only minor effort has been put into supporting the resource teachers in initiating local development.

This paper reports from a school-based PD project designed to support local development. Science teachers at a local school were invited to participate in a year-long project in which they had access to new tools and materials for science teaching. Video and other artifacts were collected from these trials and subsequently included in structured discussions in the science team. The research aim is to examine how these collaborative inquiries make sense to the involved teachers including a local resource teacher: what they identify as outcomes, how they make use of inputs and support in their classroom teaching and in collegial interactions, and how it might affect their ideas about teaching and learning science.

Theoretical Background

The theoretical reasoning behind the project is twofold: how best to support and facilitate teachers' learning, and how to research into teachers' learning.

There is a growing consensus, based on research, on the most beneficial approaches to teachers' PD. Briefly, it appears that PD gains from being school-based, long-term, content focused, and from incorporating inquiries into practice (Ostermeier et al. 2010; Desimone 2009; Roth 2007; Hiebert et al. 2002; Garet et al. 2001). Furthermore, the importance of collaboration in teacher learning communities is emphasized (Wenger 1998; McLaughlin and Talbert 2006; Stoll and Louis 2007). Research has indicated how artifacts from practice: classroom video, students' work (drawings, writings, etc.), and assessment data can be mediating tools in teachers' learning by facilitating collaborative inquiries into local practice and supporting the development of a shared language in a team of teachers (Putman and Borko 2000; Franke et al. 2010; Zhang et al. 2011). Furthermore, sharing of classroom videos in so-called video clubs has been reported to help shift the focus toward student thinking and learning (Sherin and Han 2004; Van Es and Sherin 2008; van Es 2009). Despite this understanding, we still know relatively little about the learning of teachers during PD activities (Fishmann et al. 2003). In particular, more in-depth knowledge is needed regarding individual teachers' learning, their change in knowledge and beliefs and/or in teaching practice, while participating in collaborative projects (Meirink et al. 2010).

Research into teachers' learning is necessarily a very complex enterprise, and it is seldom possible to establish a simple cause-effect relation between new input in a

PD project and the integration of such input into practice. Science teachers are involved in continual learning that is influenced by both multiple external factors as well as the teachers' own ideas about the teaching and learning of science. Some of these factors, for example, how the teachers view science as a subject, seem to be deeply rooted and hard to change. Ideas and interpretations of experience are often referred to as conceptions (Hewson and Hewson 1989; Mellado 1998) or beliefs (Pajares 1992). It has been suggested that a (facilitated) change in practice and the teacher's subsequent appreciation of the effect of his change may be needed before a change in basic beliefs can occur (Guskey 1986). Several researchers working on the professional learning of teachers have developed models that try to capture and interpret such interplays and potential mediating aspects. The interconnected model of teachers' professional growth (Clarke and Hollingsworth 2002) is based on an understanding of teachers as active learners shaping their professional growth through reflective participation in PD programs (Clarke and Hollingsworth 2002). Teachers' professional growth occurs according to this empirically based model through the mediating processes of reflection and enactment connecting four distinct domains (situated in the change environment), namely:

- External domain: information, stimulus, and support from external sources;
- Domain of practice: professional experimentation in the classroom;
- Personal domain: teacher's knowledge, beliefs, and attitudes;
- Domain of consequence: salient outcomes.

The model is claimed to be consistent with both a cognitive and a situative perspective (Clarke and Hollingsworth 2002, p. 955). This study is guided by a situative and sociocultural perspective seeing teachers' learning as individual, but situated in the social context, distributed among colleagues and mediated by a range of tools and artifacts (e.g. Borko 2004; Wertsch 1991) and seeing their meaning-making, their continual construction of understanding and interpretation of experiences as the key to conceptualizing their learning (Edwards 2001; Nichols 1997; Ebenezer 1995). The main aim is to examine individual teachers' meaning-making in the context of the local collaborative project. An additional aim that developed during the study is to adapt the interconnected model, so that it can be used to analyze and interpret teachers' meaning-making.

Research Questions

The research questions relate to a school science team's collaborative project in which team members were engaged in examining artifacts from practice in local classrooms. The questions are as follows:

1. How do individual teachers reflect on the project?
   (a) What outcomes do they identify?
   (b) To which aspects of the project do they refer?
2. What links do the teachers make between (a) and (b), and what insight into their meaning-making do these provide?

3. What ideas about the teaching and learning of science do the teachers express and how might these influence and be influenced by their meaning-making related to the project?

The Local Context

This section will begin with a short description of the Danish school system and the case school, before outlining the PD project under discussion. Details of the project itself will include information and quotes from interviews with teachers and the pedagogical leader at the beginning of the project (first round of interviews, see Table 1). But first the case school; this school offers primary and lower secondary-level education and is situated in a suburb of a major city in Denmark. The surrounding area is mixed socioeconomically. Overall, it is an average Danish school where grades 1–6 (primary) are taught integrated Science and Technology, while pupils in grades 7–9 have separate lessons for Biology, Geography, and Physics and Chemistry. The local science teachers are like all Danish science teachers for these levels educated in integrated bachelor programs at a University College (UC). Most of them took one of the science specializations during their pre-service training and have additional specializations including non-science subjects. UC-educated teachers are often referred to as generalists. In contrast, science teachers for the upper secondary level are university educated subject specialists.

All teachers who teach one of the science subjects are members of the science team. In addition, these teachers are part of other defined in school communities, such as teams for teaching a particular grade level. As is common in most Danish schools, these teams are relatively autonomous with respect to their focus, how frequently members meet, etc.

The school leadership can be characterized as development oriented and the school ethos as conducive to change (Clarke and Hollingsworth 2002): The school is used for school placements of pre-service teachers and the pedagogical leader is involved in developing cooperation between schools and teacher education to qualify pre-service teacher education and to facilitate school-based PD. Furthermore, two of the science teachers have recently finished diploma degrees in science education, enabling them to act as resource teachers and use part of their scheduled time to support colleagues. In spite of this outlook, the two resource teachers experienced considerable variation in their colleagues' engagement in developing science teaching. They consequently asked for support from a facilitator—an opportunity made possible through the existing cooperation between the school and teacher education. The facilitator is also the researcher in the study. At the start of the study, the resource teachers stated that they had experienced a positive spirit in the science team, but somewhat slow progress in both the development of science teaching and in cooperation in the team. One of them said: "When we are together in the team I actually think it is in a good spirit, but some just do not want to be moved and then there are many, who want to, but have a lot of other focus areas"; the other agreed: "As coordinators in the science team I think we drag a heavy load,

Table 1 The school-based PD project and data-collection in headlines

PD activities	Data-collection
Start August 2009	
Meeting: Facilitator, teachers in the science team and school pedagogical leader. Frames, goals, time-span etc. were negotiated	First round of interviews with participating science teachers and the schools pedagogical leader
Planning and implementing workshop 1	
Teaching sessions in two 6th grade classes working with a systematic approach to simple chemical analysis and discussing their understanding of criteria and classification were video-recorded. Teaching material was translated CASE material (Adey et al. 2001)	Video-clips from the video-recordings in the two classed used in workshop 1
Workshop 1: Discussion of 6th grade students' preconceptions and developing scientific discourse based on video-excerpts	Workshop discussion audio-recorded
Agreements were made to examine the use of similar approaches in other themes along the year, and to supplement video with other artifacts. A 3rd grade teacher asked for material to teach electrical circuits (first time teaching this theme), and artifacts from her teaching were agreed to be the theme for next workshop	
Planning and implementing workshop 2	
Drawings collected from three 3rd grade classes about how to light the bulb. This tool to shed light on primary students' preconceptions was part of teaching material provided by the facilitator. Furthermore a group of students was video-recorded while experimenting with bulbs, wires, batteries and simple electrical circuits	Students' drawings Video-clips from the video-recordings in one of the classed used in workshop 2
Workshop 2. Discussions about students' preconceptions and developing understanding of electrical circuits based on the collected artifacts. This was put into perspective by research results (facilitator) and concept cartoons (Keogh and Naylor 1999) were presented as discursive tools designed to examine alternative conceptions typically held by students	Workshop discussion audio-recorded
It was agreed to follow up on the 3rd graders in the next workshop. In addition, an examination of 5th and 6th grade students' preconceptions of cardiopulmonary physiology was planned, and so was the use of a discursive tool inspired by concept cartoons in two 8th grade classes	
Planning and implementing workshop 3	
Drawings/essays collected from students in two 8th grade classes using the discursive tool. Video-recording in one of the classes during a teaching session with group discussions. Theme was climate science in both classes	Students' drawings Video-clips from the video-recordings in one of the classes used in workshop 3
Second round of drawings collected from all 3rd grades: their understanding of electrical circuits after three weeks teaching	
Drawings/writings collected from grade 5 and 6. Grade classes. Theme was cardiopulmonary physiology	

Table 1 continued

PD activities	Data-collection
Workshop 3. Students' dialogues and developing understanding were discussed based on the collected artifacts. Facilitator contributed with research results about typical challenges for students in the actual science areas	Workshop discussion audio-recorded
A possible progression from teaching electrical circuits in Science and Technology to lower secondary Physics and Chemistry was shortly discussed	
May 2010	
Students' preconceptions about wires and electrical circuits were examined in a 7th grade Physics and Chemistry class, after the last workshop, but before second round of interviews	In-depth study: Second round of interviews with four teachers representing different levels of experience and science teaching across a range of grades

The interviews are used as the main data for the in-depth study of teachers meaning-making. Additional data, artifacts and audio-recordings, are used in the interviews

it is hard to find time to meet, but as soon as we meet, then it gives a good energy." Other teachers at the school supported this description. One lower secondary science teacher said: "We have some meetings, but you can't say that we have a real cooperation"; another said, "It is not so much we make use of each other, but there is [the resource teachers by name] who really want to do something, and can do something, and this is an inspiration." A primary science teacher said, "I know that if I need help there is someone to ask [..] but everyday life at the school is busy." However, there seems to be some cooperation around the planning of science teaching at the primary grade levels. In contrast, there are only a few teachers who teach lower secondary science, and a teacher of Physics and Chemistry and Biology noted in the first interview that: "no, there is no cooperation like that, I have lower secondary much to myself."

The PD Project

The two resource teachers initiated the PD project, but final arrangements were made at a school meeting attended by all science teachers and the pedagogical leader (see Table 1). The idea to use artifacts from practice, in particular classroom video, in structured discussions in the team to support the teachers' collaborative focus on the students' thinking and learning in science was presented by the facilitator at this meeting. Many teachers expressed reluctance to have video in their classes, but most of them were positive about participating in facilitated workshops, and it was agreed to arrange three half-day workshops for all science teachers in the team. One resource teacher volunteered to be the first to have video in her class and later in the year other teachers followed her lead, but

as the project progressed the design was adapted to include other kinds of artifacts besides video. Table 1 summarizes the activity flow in the project period 2009–2010.

The facilitator helped the teachers to experiment with new tools and teaching materials in between the gatherings of the full team in the workshops and to collect video and other artifacts to share with the colleagues. Video-clips were chosen before each workshop by the teacher from the class being videotaped with support from the facilitator. The selection criteria was the relevance of the clips to the theme of the workshop, for example, the theme in workshop 2 was agreed to be students' preconceptions about electrical circuits so video-clips showing students discussing how to light the bulb before trying it out were selected as central. The workshop discussions were structured by the facilitator who took inspiration from video clubs (Sherin and Han 2004), among other things the teachers were encouraged to focus on various ways of seeing and describing what happened before moving to interpretation as suggested by (Rodgers 2002). A workshop typically started with the teacher explaining what has been tried out in class, showing video-clips and suggesting a first focus for discussion. Afterward, the other teachers shared their observations and raised additional issues. This led to the repeated watching of video-clips to find more indications of the students' thinking and to study their argumentation. A similar approach was used to analyze and discuss other artifacts (students' drawings and writings). Furthermore, the facilitator offered input and tools from the knowledge base of research in science education regarding typical student preconceptions in the relevant science areas (see Table 1). Such alternative conceptions have been found to be extremely resistant and difficult to change and to have a profound influence on what is learned (e.g., Driver 1989; Scott et al. 2007).

The PD project was not designed to follow a pre-described program. The individual workshops and decisions about experiments in the local science classrooms were planned over the year and informed by teachers' questions, expressed desires, and formative assessment. This iterative approach, where the workshops and the teaching developed alongside each other drawing on the collaborative study of students' preconceptions and developing understanding of the science subject matter, is informed by two-level design models that link teacher learning to student learning (Fishmann et al. 2003; van Dijk and Kattmann 2007).

Methodology

Sample and Data-Collection

The aim was to understand and develop a trustworthy representation of the meaning-making of teachers involved in the PD project. Aligned to this aim, the main data were collected through semi-structured interviews to enable participants to express the meaning they ascribe to the experiences from the project and to their own development and the influences on it (Kvale and Brinkmann 2009; Cohen et al. 2007). Interview data were collected from two rounds of individual interviews. The first round took place at the start of the project before the first workshop

(see Table 1). These interviews involved a range of science teachers and the school pedagogical leader and were used to collect background data, including the school context and the teachers' personal experiences from teaching science. Four teachers were then selected for a more in-depth study that concluded with a second interview, at the end of the project. The sample was selected using purposive sampling (Cohen et al. 2007) to represent diversity: different levels of experience and teaching across a range of grades. The four teachers were the following:

- Teacher A: a novice teacher in her second year of teaching, but her first year of teaching science, specialized in Science and Technology, teaching Science and Technology in 5th grade.
- Teacher B: a recently qualified teacher in her third year of teaching, specialized in Geography, a non-specialist teaching Science and Technology across all 3rd grade classes.
- Teacher C: an experienced teacher, also a resource teacher for the science team (the other resource teacher left the school during the project), specialized in Biology and with a diploma degree in Science Education, teaching Science and Technology in 6th grade.
- Teacher D: the most experienced/senior teacher, specialized in Geography, teaching 8th grade Geography.

All four teachers contributed artifacts from their classrooms for discussion in the workshops.

The semi-structured interviews were based on interview guides, so the same phrasings were used in all interviews, but with follow-up and validating questions where necessary to offer the interviewee the opportunity to add further information and to check the accuracy of summaries (Kvale and Brinkmann 2009; Cohen et al. 2007). The interviews, which in first round lasted around 40 min and in the second round an hour, were audiotaped and transcribed verbatim, with indications of pauses and silences. The quotes are translated and used without the pause indicators that are in the original transcriptions in Danish, but marked [..] where words are missing.

Questions in the first interview focused on background and experiences in science teaching, frames, and possibilities for science teaching at the school and cooperation in general and within the science team. Furthermore, the teachers' ideas about science teaching and learning were explored by asking directly what they found most important in science teaching and the necessary attributes to be a good science teacher, and indirectly by letting the teacher's reason about specific episodes from their teaching. Questions in the second interview focused on both the teacher's science teaching during the project period and their ideas about science teaching and learning repeated from the first interview. This was followed up by asking where they saw themselves with respect to their professional growth and finally by questions relating to their experiences from the PD project. The first part of the interview was conducted without reference to (artifacts from) the project, while the second part focused on the PD experience. Here, the additional data collected, the artifacts, and transcribed dialogues of the audio-recordings from the workshops were available to stimulate the teacher's recall. The artifacts were not studied

chronologically during the interview, but when the teachers referred to specific artifacts, those were taken out.

Quality Assurance

The double role as facilitator and researcher provided a unique insight into the local context. The facilitator made frequent visits to the case school during the study-year observing and videotaping, and was involved both in the formal workshops and day-to-day discussions when supporting individual teachers in trials in their classrooms. A participant researcher can, as stated by (Cohen et al. p. 135), support credibility of the findings, but to avoid bias and blind spots caused by the double role a fellow researcher not involved in the PD project was involved in data analysis. The researchers carried out independently the final coding of all interview transcripts following a codebook (see below) and the initial inter-coder reliability was more than 80 %. Differences were then compared and discussed until agreement was reached.

Data Analysis

The interconnected model referred to above (Clarke and Hollingsworth 2002) was adapted to facilitate analysis and representation of the complex interplays in relation to the teachers' meaning-making. In Clarke and Hollingsworth's conceptualization, collegial interactions are part of the change environment. In other studies, these are seen as a particular sub-field of interest in the domain of consequence (Van Driel and Beijaard 2003; Van Driel 2010), but their adaption could not be applied directly as it does not include a separate domain of consequence necessary in the present study where teachers' perceived outcomes is a central perspective. So the interconnected model was adapted with a new domain of collaboration, but still with a domain of consequence (Fig. 1).

The domains in the model are linked by the arrows reflection and enactment to represent how change in one domain influences change in another (Clarke and Hollingsworth 2002). The analysis is based on the utterances of the teachers. When a teacher's reflection involves two domains, a reflection arrow is used between the domains; when the teacher refers to how something in one domain entails something in another domain, an enactment arrow is used (see analytical procedures below and the codebook in "Appendix 1"). The final representation is called a meaning-making map. Clarke and Hollingsworth (2002) alternate between calling their illustrations change sequences or growth networks when interpreted as more lasting growth. The new naming emphasizes the research aim: to examine and represent the individual teachers' meaning-making.

Categorizing the Teachers' Reflections on the Project (Research Question 1a and 1b)

The transcripts from second round of interviews were initially read through several times to get a holistic impression of the data. The domains identified in Fig. 1

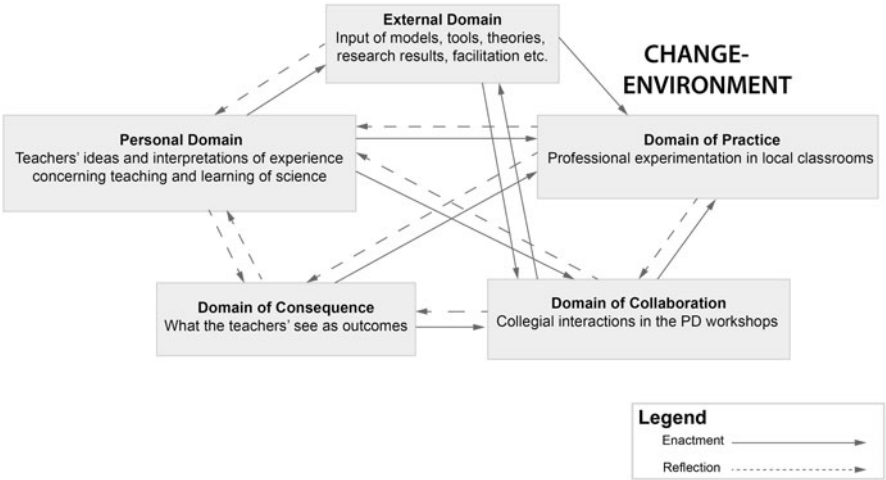

Fig. 1 Meaning-making model

provided initial coding categories, and transcripts were analyzed to identify teacher utterances relating to each individual domain (codebook, "Appendix 1", step 1). Utterances about perceived outcomes were categorized under the domain of consequence and used to address research question 1a; references to the project categorized under the other domains were used to address research question 1b. In the analysis, an utterance was defined as a single unit of meaning; any one response might contain multiple utterances and so generate more than one code. A process of constant comparison (Cohen et al. 2007; Glaser and Strauss 1967) was used to develop open coding categories that described the content of the of teachers' utterances referring to each domain. During this process, an unlimited number of subcategories were identified, and then, through an iterative process of reducing, merging, and synchronizing, these subcategories were gradually compared and refined to produce the codes. The software "atlas.ti" was used to support this analysis.

Identifying the Ways in Which Teachers Link Their Personal Outcomes to Different Aspects of the PD Project: Creating Meaning-Making Maps (Research Question 2)

Interview transcripts were reviewed, and utterances categorized as belonging to more than one domain in the first step were identified. Links between domains were represented by mediating arrows—reflection or enactment—according to the codebook, "Appendix 1", step 2. This analysis provided the arrows that, combined with the content of the domain boxes (analysis above), were used to generate a meaning-making map for each teacher. The utterances providing the links between the domains were condensed and attached to the arrow in the final representation.

For example, when asked about outcomes teacher B refers to her experience of teaching unfamiliar science content: "I think it has been really good teaching this electricity [..]they simply loved to go to the science-lab and to do those experiments individually and with the others from the class." The teacher reflects on a perceived outcome (domain of consequence) and links it to something new she has tried in her class (domain of practice), so a reflective arrow is made between these domains. Teacher B continues talking about this experience: "in discussions in class [a named boy] had the chance to show how he caught the point [..] and some students still seemed to wonder, what happens here [..] you could follow how various students, and they are very diverse, how they caught the point." A reflective arrow between the domain of practice and the personal domain represents her interpretation of experience in relation to students as learners. When referring to where she sees herself heading in her professional work looking forward, she says she wants "to try new approaches in my class, like the one we tried with electricity." An enactment arrow goes from the domain of consequence to the domain of practice, representing an intention to build on this outcome through further professional experimentation (description in the codebook, "Appendix 1", step 2: "The teacher refers to an outcome and how this entailed or might entail new/changed/more/less professional experimentation").

Teachers' Ideas About Teaching and Learning Science (Research Question 3)

To inform the interpretation of potential influences on the teachers' meaning-making, their utterances about the teaching and learning of science from both interviews were analyzed following the process of constant comparison. Four main categories: "teacher–student," "teacher-science," "student–science," and "teacher relating to student–science," with several codes in each category, emerged from this process, illustrated as the three sides and the altitude in a pedagogical triangle (Fig. 2).

The analysis provides the following example. When teacher A says "and then there are some students spoiling the teaching," it is "teacher–student"; when teacher B says "physics and chemistry is not what I am strongest in," it is "teacher-science"; when teacher B says "Science and Technology is about that they feel, touch, experience," it is "student–science"; and when teacher C says: "I have planned it using the same groups again because when you want them to express their thinking there is an enormously span in abstraction," it is "teacher relating to student–science." The codebook in "Appendix 2" describes and exemplifies all categories and codes.

Findings

The findings will be presented referring to each of the research questions.

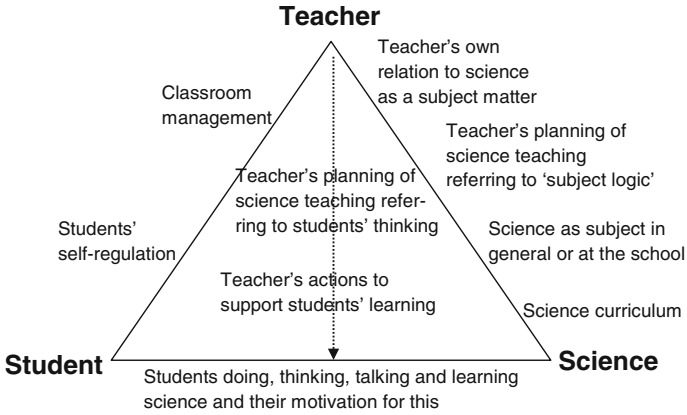

Fig. 2 The main categories condensing teachers' utterances about teaching and learning science. Codebook with full description and examples is in "Appendix 2"

The Outcomes Identified by the Teachers (Research Question 1a)

Table 2 presents an overview of the various outcomes identified by the four teachers.

All the teachers refer to outcomes related to new insights into the students' discussion. Insights from discussions aimed to examine preconceptions (teacher C's class) are emphasized by teachers A and B. Teacher B also refers to the students' discussion in her own class, while teacher A only does so when asked directly, and not as an outcome. Teachers C and D refer to the students' discussion in teacher D's 8th grade class. Teacher C says: "the 8th graders, this I think is really important, to see how the discussion runs for the students." Teacher D specifically refers to her insight into her students staying on task and discussing what they were supposed to discuss also when she was somewhere else in the classroom, and she continues: "I should use this more, make them discuss things more, it does not always need to be me as a teacher discussing with them."

The main outcome experienced by the novice, teacher A, was getting ideas for her own practice from the practice of colleagues: "To see how it is done in other classes, and also to see and hear that it can be hard in other classes sometimes." Furthermore, she refers to the facilitator's input: "concept cartoons [..] make them talk [..] gives them a starting point for argumentation." Teacher B refers to being facilitated in her first time teaching basic electrical circuits in 3rd grade, using small bulbs, wires, and batteries, as the main outcome (quoted above in Methodology). She also refers to the tools: "I personally gained from our work with how to challenge students preconceptions [..] it is important to let them put language on the science they know."

Teacher C and D refer more specifically to the use of video when talking about outcomes. When asked at the start of the project to have video in her class teacher D was reluctant, like several of the colleagues. When the project was up and running she decided to try it anyway, and in retrospect she believes this method was highly

Table 2 The outcomes the teachers identify

Outcomes	A	B	C	D
A growing insight to students' discussion				
In own class		x		x
In a concrete class taught by a colleague (based on video)	x	x	x	
Increasing confidence that students can stay on task during group work (based on video from own class)				X
Awareness of ideas/tools to use in own practice (inspiration from colleagues/facilitator)	X	x		
Experience of teaching unfamiliar science content		X		
Reinforcement of the value of posing questions rather than just giving answers			x	x
Realizing that what happens in colleagues' classrooms is not "perfect"	x			
Gaining an insight to colleagues' attitudes				
Toward developing science teaching within the school			X	
Toward cooperation				x
Recognition of the value of sharing practice	x	x		
Recognition of the value of video for self-reflection			x	x

The little x indicates all the outcomes identified. The big X indicates what the teachers emphasize as their main outcome

informative both for studying the students' work processes and her own way of posing questions: "I actually think you can use these video-recordings from your teaching, I have to admit it, though I did not like it myself because of performance anxiety." Teacher C also values video as a tool in self-reflection: "you realize the importance of keeping on asking questions though it may sometimes seem easier just to give them the answers." This refers to the video of her teaching 6th grade. Besides this, she refers to experiencing the project through the lens of a resource teacher.

These perceived outcomes are included in the meaning-making maps for each teacher below. The teachers looking forward to where they see themselves heading in their professional growth is reported across cases after individual portraits.

Meaning-Making Map, Teacher A

Teacher A did not wish to be videotaped, but during the project she collected drawings and other written artifacts from her class, used to examine her 5th grade students' understanding of cardiopulmonary circulation in workshop 3. The students in her class were asked to draw, in a pre-drawn shading of a body, the processes and functions of human blood circulation, following some lessons in physiology, where they, among other things, dissected the hearts of pigs. Teacher A did not refer to this in the retrospective interview until she was asked directly, following her spontaneous reference to what was seen in her colleagues' classrooms. However, when asked directly what she gained from this experience she reflected on and interpreted the students' drawings, saying "it is clear that they draw the heart and not the lungs […] getting the lungs in and the two circuits, it was hard for them." She also noticed that the students had a tendency to draw one-way blood circulation

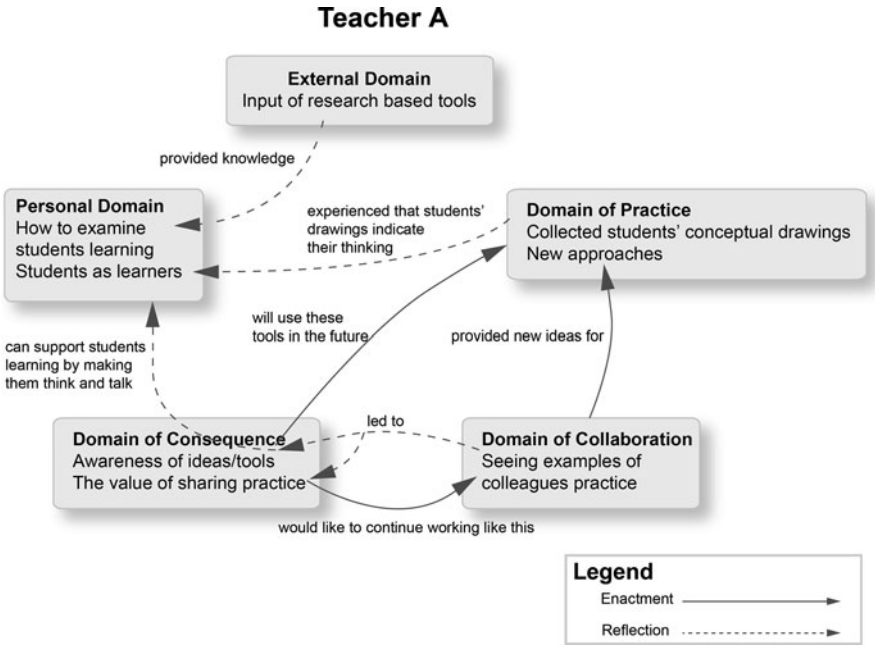

Fig. 3 Meaning-making map teacher A

out from the heart. These reflections are illustrated with a reflective arrow from the domain of practice to the personal domain (Fig. 3).

Furthermore, teacher A's map represents how she gained ideas from watching video and participating in discussions with colleagues in the workshops (domain of collaboration): how she became aware of the benefit of using tools to examine students' preconceptions. This leads to the personal domain, as does input from the external domain while she reflects on how tools like concept cartoons presented by the facilitator can be used to explore student learning. In the first interview, before the project, teacher A only mentions cooperation with the other teachers from 5th grade, but in the second interview, she specifically refers to the full science team when looking forward from the experience of sharing practice: "we need to be better to sit down all of us, we have missed this, what did students learn at one grade and how do you move on."

Meaning-Making Map, Teacher B

As mentioned earlier, teacher B taught electrical circuits for the first time during the project and she refers to the teaching material she received: enactment arrow from the external domain to the domain of practice in Fig. 4. The teaching material involves continuing shifts between students posing hypotheses, their progressing experiments, and class and group discussions. Various artifacts from her 3rd graders were discussed in workshops 2 and 3. Preconceptions from many 3rd graders were identified in discussion during the workshops in relation to only one connection

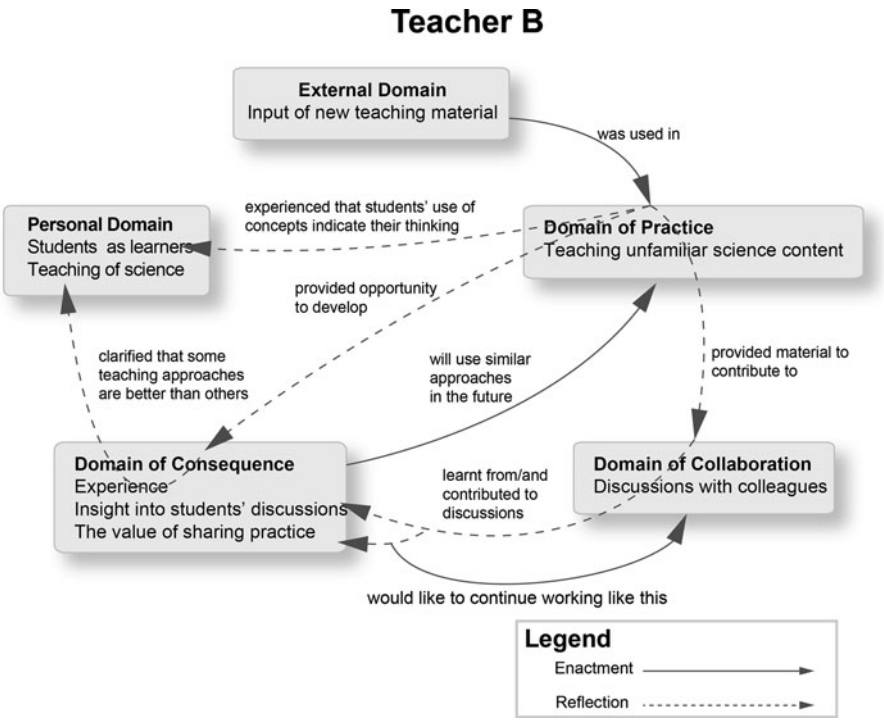

Fig. 4 Meaning-making map teacher B

needed from bulb to battery or two "arrows" from the battery meeting in the bulb. The teachers noticed how all the students after a few lessons referred to circuits and most students specifically attached the wire to two different places on the drawing of the bulb.

Nearly all teacher B's reflections are connected to this positive experience, so domain of practice can be seen as the key domain in her meaning-making map. The experience seems to have clarified for her that some teaching approaches are better than others: reflection from the domain of consequence to the personal domain. Referring back to previous experiences at a local resource center where her former classes have been working with electricity, she states that too much emphasis was placed on "science as a show" compared with the focus on students' thinking used now. Like teacher A, teacher B emphasizes the facilitator's input of tools, like concept cartoons and research results (students' typical preconceptions). She also values being able to contribute to the workshops with artifacts from her classes. In retrospect, she sees herself as having been passive in the science team before: "I didn't feel before that it was my field, I do not have very much physics."

Meaning-Making Map, Teacher C

Teacher C, the resource teacher, was the first to be videotaped. Her teaching in two 6 grade classes involved examining students' preconceptions and their experiments

with simple chemical analysis. The emphasis in the CASE teaching material she used was on the systematic approach: before doing experiments, the students discussed in groups what a criterion is and what classification is (Adey et al. 2001). She knew this material from her recent diploma in science education and she wanted, as a resource teacher, more colleagues to be aware of it. Teacher C also supports her teaching approach based on her existing knowledge about the students and how to challenge them: "Now we are in 6th grade and they are cognitively ready to make those connections."

Teacher C has the most complicated map (Fig. 5) as nearly all her considerations involved extra meta-cognition from being both a resource teacher and a classroom teacher. She planned her teaching to be videotaped based on considerations both as a classroom teacher and as a resource teacher. Reviewing video informed her own practice; she mentions the value of asking questions instead of just giving answers, and she refers to the value of video for self-reflection. The project also informed her as a resource teacher, providing insight into her colleagues' practice, in that way the domain of collaboration can be seen as another domain of practice for her. She reflects on how you "learn as a teacher by seeing/doing it yourself, not just by being told," and exemplifies that the importance of examining students' preconceptions had been discussed in the team before, but the colleagues seem to react differently now when seeing classroom examples on video. She continues: "there was only one who was not there in the last workshop, it shows it has been useful for the colleagues, there is a good example with E [a physics teacher] when we discussed electricity in 3rd grade, it was connected to the older students also, and to Physics, and afterward he tried some of the things, we had discussed." Being a resource teacher can be challenging, and teacher C has developed an awareness of personal developmental needs through the project. She refers to one-to-one discussions with the facilitator and says she was inspired by the way the workshops were facilitated, taking account of her colleagues' responses.

Meaning-Making Map, Teacher D

During the project, teacher D tried a tool inspired by concept cartoons to encourage 8th graders' to discuss the earth's climate (*Why is it hotter in Africa than in Europe?*). The students in groups discussed three various suggestions by named imaginary young people. The 8th graders were very engaged in the discussion, which was contrary to what teacher D had expected; she had thought that this was "a piece of cake" for them, as the theme had been taught in 7th grade. In workshop 3, the students' misconceptions, such as distance from the earth as an aspect rather than tilt and angle of incidence, were identified. However, the video and post-lesson drawings/essays from the students revealed how they, through discussion and purposeful questioning from teacher D moving from group to group, developed largely scientifically correct explanations, expressed in their own words.

Teacher D's Meaning-Making Map (Fig. 6) looks very much like teacher B's, but the experience of being videotaped per se is a main focus, that she challenged herself to try it, and besides this her reflection on her students' learning. She does not mention her presentation of video in workshops as teacher B does; it is her own

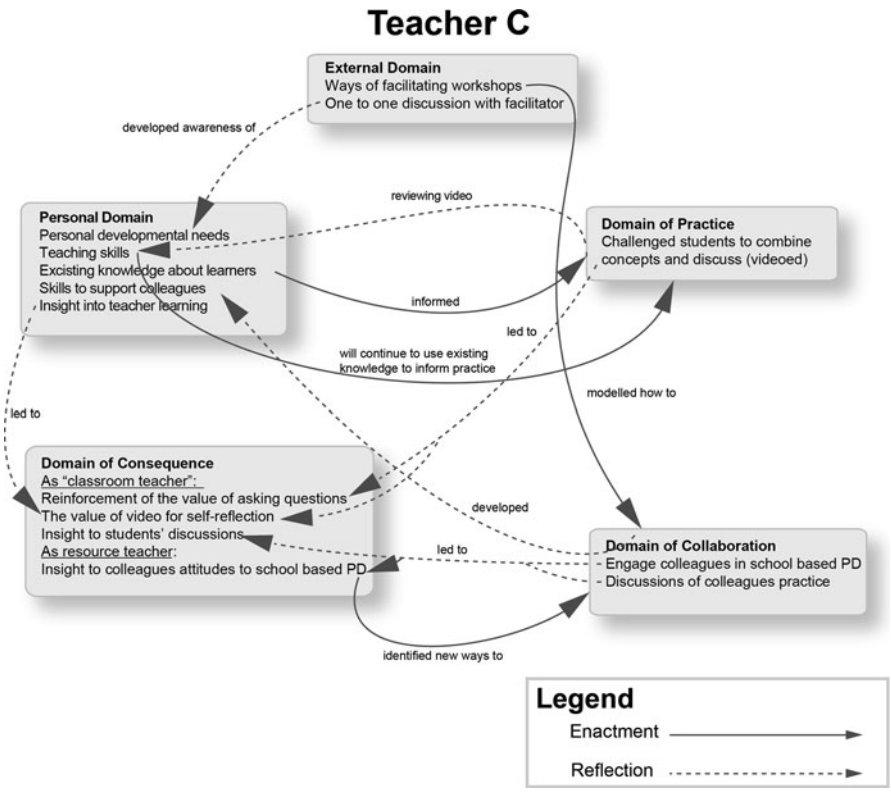

Fig. 5 Meaning-making map teacher C

self-reflection that she sees as an outcome. She refers to the science team as individuals pulling in various directions and emphasizes the lack of cooperation between lower secondary science teachers. The project, however, has provided her with evidence of some colleagues' willingness to collaborate.

Where the teachers see themselves heading in their professional growth is represented as enactment arrows from the domain of consequence to the domain of practice for teachers A, B, and D. Teacher A wants to be better at planning experiments and at supporting this through the use of discursive tools. Teacher B imagines continually developing as a science teacher by trying similar approaches in other themes, like those used to teach electricity. Teacher D states that she will use more student discussions. Teacher C thinks as both a classroom teacher and a resource teacher also when looking forward. She says she will continue trying out theory from her diploma in her own teaching and also developing her role as a resource teacher. The former utterance is represented in the loop between the personal domain and domain of practice (Fig. 5). All four teachers furthermore have enactment arrows from the domain of consequence to the domain of collaboration. They look forward to continual work with collaborative sharing of classroom

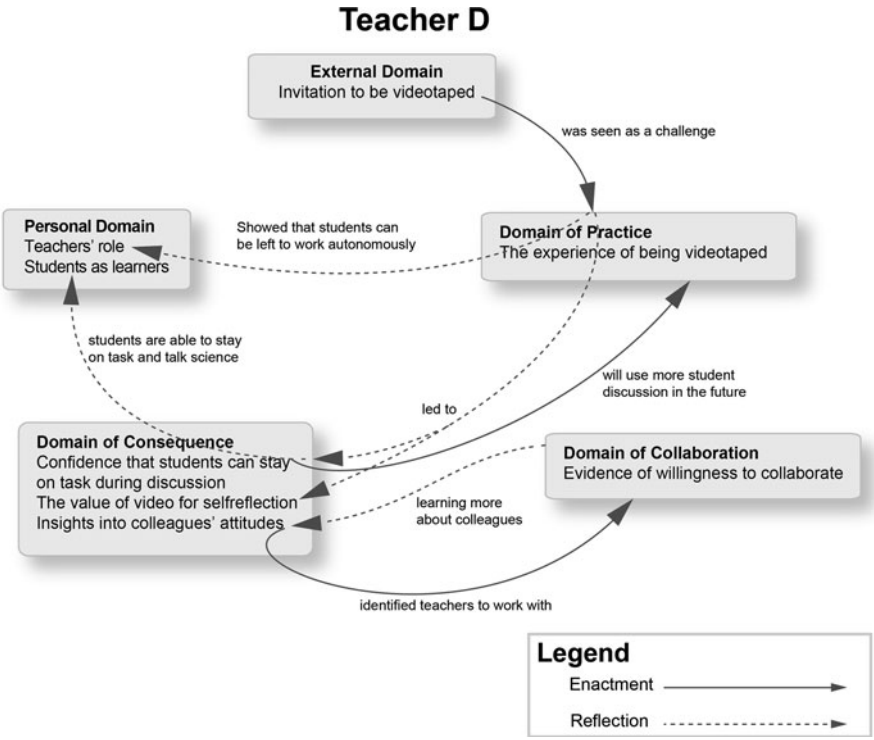

Fig. 6 Meaning-making map teacher D

practice. As teacher B says, "I think it really pulls things forward to work like this in a science team."

The Teachers' Ideas About Teaching and Learning Science (Research Question 3)

The teachers' expressions about the teaching and learning of science in both interviews, based on general interview questions not particularly connected to the project, were analyzed to inform a discussion of their "forward pointing journey through the project." Table 3 illustrates the results.

In the first interview before the project, all the teachers were positive about science as a school subject, but teacher A and B also found it a hard subject to teach and had an experience of lack of subject matter knowledge in the physics area. For teacher A, the positive attitude arises from science being a subject in which it is possible to take an alternative approach that is free, active, and potentially motivating. Teacher B agrees: "I like science, it is a subject where they have to touch and experience themselves," but she has also through her three years of teaching experienced the importance of a high degree of teacher regulation during students' activities. The two experienced teachers C and D also refer to the importance of teacher regulation. Besides being positive, teacher A states that

Table 3 Teachers' expressions about teaching and learning science

	A		B		C		D	
Category: teacher–science	1. Int.	2. Int.	1. Int.	2. Int.	1. Int.	2. Int.	1. Int.	2. Int.
Relation to science								
Feel secure					X		X	
Feel a lack of subject matter knowledge in physics	X		X					
Planning science teaching with reference to "subject logic"			X				X	X
Science as a subject								
Like science	X	X	X	X	X	X	X	X
Find science hard to teach	X		X					
Science curriculum						X	X	X
Category: teacher–student								
Classroom management								
Is a big problem in science teaching	X							
Is an issue, but works OK for me		X	X	X				
Students' (self-regulation)								
Freedom is important	X	X						
Regulation is important			X	X	X		X	
Category: Student–science								
Teacher refers to as important:								
Students' activities in science	X	X	X	X	X	X	X	X
Students' thinking in science		X		X	X	X		X
Students' talking science		X	X	X	X	X		X
Students' learning science		X		X	X	X	X	X
Students' interest and motivation	X	X	X	X	X	X	X	X
Category: teacher relating to student–science								
Planning science teaching with students thinking as the starting point					X	X	X	X
Teacher refers to actions to support students learning		X		X	X	X	X	X

The four categories refer to Fig. 2 and the codebook in "Appendix 2"

Science and Technology is a hard subject to teach as it is so broad and she refers to having problems with classroom management, stating that she sometimes has to change plans and let the students do written work instead of experiments. In the first interview, she refers very much to science as a subject with hands-on activities, but Table 3 shows a new emphasis in the second interview on students' talking science and their thinking and learning in science (minds-on). Teacher B also refers to students' talking science in both interviews, but in the second, she additionally emphasizes the importance of analyzing the students' thinking to be able to support their learning.

Table 3 indicates more stability in the experienced teachers' ideas about teaching and learning science. The two teachers can be seen as being at a stage in their careers where the basic ideas are consolidated, or at least, this study did not elucidate many signs of development, as is the case for teachers A and B. Teacher C in both interviews refers to integrated work with students' experiments in science and their talking science, and to how she as a teacher can focus on the students' learning. Teacher D expresses many of the same perspectives on science teaching and learning as does teacher C, including teachers' planning with students' thinking as a starting point and other actions to support student learning. However, it is worth noting that teacher D in the second interview refers frequently to students talking science and the importance of their discussions, contrary to the first interview, and she reflects on how to use more autonomous group-work looking forward.

To sum up, teacher A and B's ideas about teaching and leaning science seem to be very much influenced by the PD project and the examination of students' preconceptions and discursive science activities experienced in own and colleagues' classrooms (video). These ideas seem to have been incorporated in teacher C repertoire before the project. For teacher D, a slight change in emphasis on students' discussions is noticed.

Discussion

The specific findings linked tightly to the data are now followed by more interpretative discussions organized under the headings of four main assertions.

Assertion 1 *The teachers seem to emphasize outcomes from the PD project in areas where they feel supported in relation to tensions and challenges in their respective professional practice.*

Teacher A's expressed idea about active self-regulated students seems to create a tension in relation to her coping with challenges in classroom management; so does her expressed wish to be able to answer all the students' questions, as she does not feel confident in physics. It is not surprising that novices struggle with classroom management; it is seen in many studies. In relation to her meaning-making, the interesting issue is that through her journey in the project she seems to be in a process of developing her ideas. This provides a background by which to understand her emphasis on inspiration from colleagues, which seems to help her in this area of tension by inspiring and providing tools for her to see science as more than just students' hands-on activities. Low self-efficacy (context-specific judgment of own capability: Bandura 1982) in the area of physics is also expressed by teacher B. Both activity orientation, emphasizing more what students do than what they learn in science, and low self-efficacy, for example, related to teaching simple electricity in primary science, are more general challenges among novice Danish science teachers (Nielsen 2011). For B, the positive experience of teaching electrical circuits and presenting in the workshops, including the fact that video from her class inspired one of the physics teachers, seems to help her both in her own teaching and as an

active team member. The experience might balance her relatively low self-efficacy in relation to the physics content.

Teacher C is in a process of developing competence as a resource teacher, a potential coordinator in a teacher learning community, who can help build the practice of group learning (McLaughlin and Talbert 2006). She emphasizes outcomes related to acting in this double role of classroom teacher and resource teacher. The key to understanding teacher D's meaning-making might be her frustration regarding the lack of cooperation between the lower secondary science subjects. She refers to the science curriculum to back this frustration: "I would like us, just sometimes, to follow what is actually stated in the curriculum, to make cross-disciplinary themes." Her reference to performance anxiety implies that there is a threshold she needs to pass to be able to share her huge experience with colleagues, and she specifically emphasizes challenging herself to have video in her class during the project. So, perceived outcomes can also for her be seen as related to tensions from her professional work.

The emphasis on personal–professional needs can also help understand the teachers' reference to the various artifacts used in the project. All the teachers use the artifacts in their detailed interpretations regarding students' learning of science in concrete situations. It is, however, not the same kind of artifacts they refer to when reflecting about outcomes; they seem to emphasize artifacts they each can see how to use in own practice. The difference between referring to video reflection and pointing to concrete tools like concept cartoons might be related to the various challenges and needs in the teachers' professional life, and how they see the immediate use of inputs in relation to those. The two experienced teachers can explain what they gain from sharing the video-based artifacts, including the value of video in self-reflection, while the two novices apparently are inspired to incorporate strategies for eliciting students' thinking in class and to use new tools like concept cartoons. Concept cartoons are based on research results (Keogh and Naylor 1999), but the gap to practice is bridged for the teachers, so to speak, making it relatively simple for them to implement the research-based knowledge into their classroom practice.

Assertion 2 *Some patterns in the teachers' meaning-making maps seem to be of a more general character, for example, related to experimenting with new approaches.*

The four teachers as stated follow individual trajectories (Clarke and Hollingsworth 2002). In retrospect, they identify outcomes connected to current tensions as they experience them in their professional work. However, there seems to be patterns of a more general character. One example is teacher B's perceived outcomes from experimenting with new approaches and her plans for new experiments based on these outcomes. It has a close resemblance to patterns in teachers' learning mentioned in previous studies (Guskey 1986; Clarke and Hollingsworth 2002). Experimenting: purposefully trying out something new in practice combined with reflection about it is one of the most frequent learning activities reported by teachers in a quantitative longitudinal study (Bakkenes et al. 2010). Teacher D's meaning-making map shows nearly the same pattern, though

teacher B's experience of outcomes is further substantiated by her positive experience of a new role in the team.

Teacher A and C's maps do also illustrate reflections on experiments in domain of practice. Teacher A's reflections reveal her interpretation of students' learning based on a minor experiment in her classroom, and teacher C uses the focus on students' learning in her loop between the personal domain and the domain of practice. Getting ideas from colleagues' practice, which is described by teacher A as her main outcome, is also referred to by Bakkenes et al. (2010) as frequently reported by the teachers in their research. Artifacts shared in collegial interactions seem to give the novice teacher some event-structured knowledge (Nichols 1997) to help her see how the input from facilitator and colleagues can be used in concrete classroom situations. It might be that this way she, as the most junior staff member, gets ideas and efficacy to experiment more purposefully in her own practice as a potential next step.

Assertion 3 *The teachers seem to ascribe meaning to, and make continual use of, inputs from external domain when those are connected to concrete events in local classrooms with improvement in students' learning opportunities, that is, students manipulating both science ideas and equipment in ways the teachers appreciate.*

The inputs from external domain during the PD experience have been closely connected to the enactment of experiments in and reflection on shared artifacts from local practice. Ways to examine students' preconceptions and support them in talking science, discussed before as important in the science team, now seem to be developing as a part of more teachers' repertoire. It appears to be quite important in relation to development in the teachers' ideas about teaching and learning of science that the artifacts from practice collaboratively discussed, and the inputs from external domain have referred to concrete examples where students manipulate science ideas (minds-on) as well as equipment (hands on). Clarke and Hollingsworth (2002) and Guskey (1986) have exemplified and discussed how teachers' perception of salient outcomes—that they experience improvement in their students learning—can be determent for their continual use of input from PD and for their gradual changes in beliefs. Teachers' meaning-making within the PD experience in the present study has exemplified this in a science-specific context and related to a Danish challenge of prevalent activity-based science teaching: hands on without much minds-on (Nielsen 2011).

Assertion 4 *The teachers seem to be encouraged to continue developing collaboration in the science team by the experience of gaining from the facilitated collegial interactions.*

All four teachers refer to gaining from the collegial interactions during the PD experience. Teachers A and B refer to recognizing the value of sharing practice specifically as an outcome, something new they have grown to be aware of, while teacher C, the resource teacher, and teacher D apparently have been struggling to develop a more collaborative approach at the school for a while. Guskey (1986) as stated claim that a facilitated change in practice, leading to results in students' learning that the teacher appreciates, may be needed before a change in basic beliefs

can occur. Parallel to this, it can be said that in this project facilitated collegial collaborations around teaching and students' learning of science, leading to outcomes the teachers appreciate and see the use of in their individual practice, seem to encourage a continual effort to develop collaboration in the team.

Implications and Perspectives

Looking forward, the findings have implications both for research into the professional learning of teachers and for the design of school-based PD.

Representing teachers' meaning-making, their construction of understanding and interpretation of experiences, as meaning-making maps has in this study supported an insight into the complex patterns and interplays related to teachers' learning in the frames of a local PD-initiative. More experiences from using such representations are surely needed. In particular, it must be taken into consideration that the understanding of the teachers' meaning-making was further developed when it included their ideas about the teaching and learning of science, that is, when the investigation went behind the utterances about this particular PD project and identified potential influences not immediately obvious in the teachers' references to outcomes.

In relation to the design of teachers' PD, this school-based project seems to have opened-up the possibility for the individual teachers to acknowledge tensions and challenges they experience in their day-to-day practice. This was facilitated by the project's iterative design and the possibility for the teachers to engage in various ways and in various tempi. Rather than a specific PD-method per se a determent factor for successful PD might be to provide a possibility for teachers to become involved in experiments in local classrooms and provide artifacts for sharing collaboratively with input from external domain explicitly connected to those experiments and artifacts. Furthermore, the external support of a science resource teacher in this project was a successful integrated part of the study and might also prove so in other local contexts. However, the PD project was not without challenges. Video is a promising mediating tool in teachers' PD, but working with video involves thresholds that some teachers have to pass, and in this project, video was combined with other artifacts. The project continued in 2011 with faded external facilitation, so the facilitated approach has inspired a continuing local effort to qualify science teaching.

Appendix 1: Codebook, Meaning-Making Model

Step 1 Codes referring to the five domains in the meaning-making model. The teachers' utterances in this step of analysis might have reference to more than one domain.

Code	Description
External Domain (ED)	Reference to new information, materials, and stimulus from the facilitator; for example, new teaching materials, tools to be used in classrooms to examine students' preconceptions, and facilitation connected to video-recording and choice of clips to use in workshops.
Domain of Practice (DoP)	Reference to purposefully trying something new in practice; for example, trying a new tool or teaching a new subject matter area or using a new pedagogical approach in the teacher's own classroom.
Domain of Collaboration (DoCoI)	Reference to collegial interactions in the PD workshops; for example, discussion with colleagues, seeing something in colleagues practice, or presentation of artifacts from own class.
Domain of Consequence (DoCon)	Reference to something the teacher sees as an outcome from the project when being asked directly and something the teacher spontaneously refers to as an outcome.
Personal Domain (PD)	Reference to the teachers' ideas and interpretations of experience concerning the nature and content of science, science subjects and curriculum, the learners and learning of science, and decisions and planning in relation to teaching science.

Step 2 Codes referring to how change in one domain is connected to other domains, with reflection (***R***) and enactment (***E***) as mediating factors (see arrows in Fig 1). Coding is used on utterances where *more* than one code is attached in step 1.

Code	Description	Examples
PD ***E*** ED	The teacher refers to personal request and search for new information from ED.	No examples
ED ***R*** PD	The teacher reflects on personal use of input from ED.	Yes concept cartoons [..] I have to try it out (Teacher A) this is the best sparring you can get (Teacher C)
ED ***E*** DoP	The teacher refers to trials based on input from ED or supported in other ways by facilitator.	This electrics as we used it (Teacher B) I actually think you can use these video recordings, I have to admit it (Teacher D)
PD ***E*** DoP	The teacher refers to the ideas behind an initiation of experimentation in practice.	Now when I have 6th grade, I try to challenge the students to combine concepts and discuss (Teacher C)
DoP ***R*** PD	The teacher reflects on personal experiences from experimentation in the classroom—experiences which may have verified or potentially changed ideas.	Like for example in this electrics, to work with students' preconceptions, how they catch the point (Teacher B) how you can remain asking question [..] it is easier to give the answers (Teacher C)
ED ***E*** DoCoI	The teacher refers to input or support by facilitator in relation to collegial interactions in the workshops.	I think it was a good refinement in the approach made after the first workshop [..] and E tried it out [..] It is where you can see that things is now really on the track (Teacher C)

Appendix 1 continued

Code	Description	Examples
DoCoI ***E*** ED	Collaborative request and search for new "information" from ED when involved in collegial interaction.	No examples
DoCoI ***E*** PE	The teacher refers to how discussions in workshops lead to/induced/started professional experimentation (or might do so, looking forward).	This [a method seen on C's video] I would really like to use, I think it is a really good approach (Teacher A)
DoP ***R*** DoCoI	The teacher reflects on how experiments from the classroom were used in the workshops.	Something, where I could contribute [..] it was more my field (Teacher B)
DoCon ***E*** DoCoI	The teacher refers to salient outcomes and how these entail (or might entail) new/changed/more/less collegial interactions.	I think it could be fine, if we could carry on with this in the team. (Teacher B) We are going to make this project next year. (Teacher C)
DoCoI ***R*** DoCon	The teacher reflects on something that happened in collegial interactions as being a salient outcome.	I think it was really good to see how it was done in other classes. (Teacher A)
DoCon ***E*** DoP	The teacher refers to salient outcomes and how these entail (or might entail) new/changed/more/less professional experimentation.	Try new approaches, like this electrics, and work with students' preconceptions (Teacher B)
DoP ***R*** DoCon	The teacher reflects on professional experimentation, things that happened during experimentation, and/or results of experimentation as being salient outcomes.	I think it has been really good teaching electrics. (Teacher B) Students could discuss scientifically, use the concepts and stay on task (Teacher D)
DoCon ***R*** PD	The teacher refers to what is a salient outcome and when reasoning directly reflects on—or indirectly refers to personal ideas.	It makes them talk and think a lot. (Teacher A) I think this is a good approach in 3rd grade, before I used this guy from the energy-center, this was a show [..] focus on entertainment. (Teacher B)
PD ***R*** DoCon	The teacher uses ideas about teaching and learning science directly in reflection on what she sees as salient outcomes.	I think it is best that you [as a teacher] see it yourself, instead of just being told. (Teacher C)
DoCol***R*** PD	The teacher reflects on personal development, ideas about teaching and learning science, based on discussions in collegial interactions.	I think I have been thinking as a resource teacher in the workshops, the things we have discussed, I have gained a really good sense of where the colleagues are. (Teacher C)
PD***E*** DoCol	The teacher refers to ideas about teaching and learning science and uses these as an argument for new/changed/more/less collegial interactions.	No examples

Appendix 2: Codebook, Utterances About the Teaching and Learning of Science

Codes	Code description		Examples
Category: teacher—science			
Teacher's relation to science	Utterances about the teacher's relation to science as a subject matter field; the teacher's experience of the subject matter knowledge in science	Feels secure	Oh this, I feel I know and can handle (Teacher D in 1. Interview)
		Feels a lack of subject matter knowledge	Physics and chemistry this is not what I am strongest in (Teacher A in 1. interview)
Teacher's reference to planning—subject logic as the starting point	Utterances about how and what the teacher plans with reference to the logic of the science sub-content field See also the code "Teacher's reference to planning- students thinking" as the starting point' below		Earlier this year we had a theme about the geological circuit [..] and worked with various stones. (Teacher D in 1. Interview)
Science as a school subject	Utterances about science as a subject in the school system in general or at the local school	Positive comments	I like teaching science [..] it is a subject where they have to touch and experience themselves. (Teacher B in 1. Interview)
		Negative comments	In Science and Technology there are questions in south and north. (Teacher A in 1. Interview)
			When you want to make an experiment you can use really long time to find some of the things. (Teacher A in 1. Interview)
Science curriculum	Utterances referring to the Danish science curriculum: "Faelles Maal"		I would like us to follow "Faelles Maal 2", where it is actually stated that you must teach interdisciplinary themes. (Teacher D in 2. Interview)
Category: teacher–student			
Classroom management	Utterances about how the teacher copes with classroom management (and why) and problems with handling classroom management	Is a big problem in science teaching	And then there is some, ruining the teaching (Teacher A in 1. Interview)
		Is an issue, but works ok for me	It can still be a little hard, but it works and maybe you cannot avoid this. (Teacher A in 2. Interview)
			You have to be really structured (Teacher B in 1. Interview)

Appendix 2 continued

Codes	Code description		Examples
Students' self-regulation	Utterances about students deciding (or co-deciding) themselves how to approach something and/or what to do in science lessons (or teacher wanting/not wanting them to do that)	Freedom is important	I want it to be as free as possible. (Teacher A in 1. Interview)
		Regulation is important	I would never start a project like that, so unregulated, I would make a structured manual of a kind. (Teacher D in 1. Interview)
Category: student–science			
The teacher refer to as being important:			
Students doing/ activities in science	Utterances about students' activities: their hands-on experiences, experiments etc. (or lack of activities)		Science and technology is about, they feel, touch, experience. (Teacher B in interview 1)
Students thinking in science	Utterances about how students understand/ misunderstand science concepts and which concepts are easy/difficult for students		To get their preconceptions on the table (Teacher C in 1. Interview)
Students talking science	Utterances about students talking and discussing in science (or lack of it)		Bring the things inside and put some words on, about science [..] symbolic language (Teacher B in 1. Interview)
			It is important to make them talk [..] about what they know, before starting. (Teacher B in 2. Interview)
Students learning science	Utterances about students' learning or lack of learning in science (this code will often be used together with the codes above, in utterances about, for example, how students learn through talking or doing science)		Along the year [..] taking pictures, 4th grade, they were not able to make those connections (Teacher C in 1. Interview)
			This about the lungs and the two circulatory systems was a little hard for them. (Teacher A in 2. Interview)
Students' interest and motivation	Utterances about what interest and motivate students		Students who discovered some things [..] and were interested (Teacher A in 1. Interview)
Category: teacher relating to student–science			
Teacher's reference to planning—students' thinking as the starting point	Utterances about how teachers plan and/or refine teaching based on knowledge of or considerations about students' thinking and learning See also the code "Teacher's reference to planning—subject logic as the starting point" above		I have planned it using the same groups again [..] because when you want them to express their thinking [..] there is an enormously span [..] in abstraction. (Teacher C in 1, interview)
Teacher's reference to other actions supporting students' learning	Other utterances about how teachers can support students' learning processes		Photosynthesis [..] all the time a poster with a great leaf was hanging in class, and this is what they refer to now (Teacher C in 2. Interview)

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Appendix 3

Paper III

Nielsen, B.L.: Pre-service teachers' meaning-making when collaboratively analyzing video from school practice for the bachelor projects at college. *Submitted spring 2012 to Journal of Teacher Edcuation*

Pre-service Teachers' Meaning-making when Collaboratively Analyzing Video from School Practice for the Bachelor Project at College

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Abstract

This study follows a group of student teachers facilitated in collaboratively analyzing video from school practice for their bachelor projects. Their meaning-making is examined: i.e. what they experience as outcomes, how they construct understanding, and how their interpretation of classroom experiences are influenced. Findings are that the structured collaborative analysis seems to support the student teachers in more nuanced consideration of concrete incidents and in reconstructing their experiences with a focus on the students' learning. They note the benefit of support from peers during the project and they refer positively to the structured approach used for the video-analysis. Additionally they found that starting with concrete experiences before applying theory was helpful, although many did resort to more general abstractions in their reports. Alignment between intended learning outcomes, the framing of the task of making a bachelor-project and evaluation seems to be essential to support STs in developing competences in learning from practice.

Keywords: teacher education, meaning-making, video analysis, collaborative analysis, bachelor project

Introduction

Two important interrelated points often identified in research and development in the field of teachers' professional development are: 1) Teacher development does not stop after initial teacher education, there is a

continuum from pre-service teacher education into in-service teachers' professional learning, 2) Student teachers (STs) need to acquire competencies to continually learn in and from practice i.e. competence to analyze teaching in a nuanced way in terms of its effects on students' learning (e.g. Feinam-Nemser, 2001; Rodgers, 2002; Hiebert, Morris, Berk, Jansen, 2007).

This paper reports from a local attempt to support STs in developing such reflective competencies by facilitating them in collaboratively analyzing video-clips of classroom interactions from their school practice, to be used in their bachelor projects. The aim is to examine the STs 'learning' from this experience: how they make use of inputs, how their interpretation of classroom experiences might be influenced, and what they experience as personal outcomes.

Background

STs development of competencies to learn from classroom practice is seen as important in contemporary reforms of pre-service teacher education throughout the world (e.g. Korthagen, Loughran and Russell, 2006), and has been embedded in the Bologna competency profile for a professional bachelor degree[1]. In response to the Bologna declaration, intended learning outcomes have recently (in 2007) been refined in the Danish four-year integrated BEd program to increase the emphasis on STs' analyses of classroom interactions. But it is one thing to refine the intended learning outcomes, and then it is quite another issue to change practice in pre-service teacher education accordingly.

The complicated interplay between theory and practice has been discussed for decades in research (e.g. Calderhead, 1988; Korthagen, 2008). Calderhead (1988) argues that the relationship between theory and practice has to be continuously interactive and STs need to develop a repertoire of metacognitive skills to continuously evolve in the experimental process of learning in the classroom. Korthagen (2008) adds that what is helpful for STs in the process of solving problems in the classroom is what he calls small principles t-theory.

[1] Bologna declaration: www.ehea.info/. The Danish Bologna qualifications framework: www.vtu.dk/fsk/div/bologna/DanishQFReport.pdf

Generalized abstractions (T-theory) need to be connected to sufficient practical experiences in which the theory is consciously used. Though 'reflective practice', teachers' learning from reflecting on practical experiences, continues to be a contested term (e.g. Oner and Adadan, 2011), and though few definitive statements about the effects of different models for pre-service teacher education can be made based on research (Cochran-Smith and Zeichner, 2005), the importance of opportunities for STs to collaboratively inquire into and problem solve based on concrete classroom experiences is recognized in a range of reform programs (Korthagen, Loughran and Russell, 2006; Darling-Hammond, Hammerness, Grossman, Rust and Shulman, 2005; Darling-Hammond and Sykes, 1999).

The complexity of factors that might potentially have an impact on STs' learning is also acknowledged. Several researchers have tried to capture and interpret such interconnections and potential mediating aspects.

Edwards (2002) and Borko (2004) refer to teachers' learning as situated agency, not as something being done to the teachers, but as their ongoing development of capacity to interpret the affordances of particular situations and change their actions accordingly. Following from this STs' learning can be conceptualized as their *meaning-making*: their construction of understanding and interpretation of experiences situated in particular settings and contexts (Nielsen, 2012; Edwards, 2001; Nichols, 1997; Ebenezer, 1995; Wertsch, 1991).

The situative view has to take into consideration learning/meaning-making as a (partly) social process: There is a growing acknowledgement of the role of peer-collaboration in relation to an individual's learning (Sherin, Linsenmeier and van Es, 2009; McLaughlin and Talbert, 2006; Wenger, 1998) and with respect to teachers' collaborative inquiries the sharing of video clips from classroom practice has been identified as a potential mediating tool (Sherin and Han 2004; Sherin et al., 2009; Eilam and Poyas, 2006; Rosaen, Lundeberg, Cooper, Fritzen and Terpstra 2008).

These strands of research informed the initiative to include collaborative video-analysis in the Danish BEd program. As a consequence of the recent refinements in the intended learning outcomes the STs have to include some

kind of classroom artifacts in their bachelor project. But it is well-known that STs find analyzing concrete incidents a challenge. They typically need structured approaches to gain from analyzing video or other classroom artifacts (Rich and Hannafin, 2009; Rodgers, 2002). This was the background for the present research and development initiative to facilitate and structure STs collaborative analysis of video from their school practice, so that they would have an artifact they could use in their project.

The participating STs followed the normal teacher training, but were additionally offered a week of full-day collaborative analytical workshops after their individual collection of video during school practice (table 1). Each workshop started with one of the STs explaining what had been tried out in class and presenting video clips. After this the other STs contributed, and some video-clips discussed were replayed several times. The structured approach framing the workshops was inspired by the Rodgers (2002) and consisted of three main steps: 1) description, 2) analysis and 3) interpretation: In step 1, the STs were encouraged to describe the incidents from various viewpoints. In analysis in step 2 the STs used a newly developed tool for video analysis of classroom interactions with a range of evidence-based categories to analyze teacher and student interaction. They stated to be familiar with technical tools for video-analysis and so were given the opportunity to use their preferred option.

The analytical tool suggests three main categories to be used in analysis of classroom interactions: A) school students' communication and engagement, B) teacher's questions and responses and C) approach to subject matter (appendix A: Andersen and Nielsen, 2011). In step 3) the STs discussed various ways of interpreting school students' learning and factors influencing it in the particular incidents, and the ST presenting the video summed up.

The research questions in this particular context are:

1) Do the students teachers' interpretation of their classroom experiences change after being involved in the process of collaboratively analyzing video artifacts for their individual bachelor projects, and if so, how?
2) What do the STs themselves emphasize as outcomes from the collaborative video-analysis

3) What further insight into their meaning-making is gained when looking into critical moments in workshop-dialogue illuminating issues raised by the STs in 1) and 2)?

Methodology

Sampling was of convenience type (Cohen, Manion and Morrison, 2007). All BEd students who had a bachelor project related to a science specialization were given the opportunity to participate; four expressed an interest and went on to participate. The four STs, three female and one male, are all in their mid-twenties. They did not know each other in advance and had not worked together before. For anonymity reasons the STs are given a pseudonym:

- *Marie*, specialized in Danish, Geography, Social Science and Sports
- *Christian*, specialized in Mathematics, Biology, Social Science and Physics & Chemistry.
- *Jane*, specialized in Mathematics, Geography, Social Science and History.
- *Louise*, specialized in Mathematics, English, History and Geography

Context: During 4 weeks of school practice the STs individually collected video of those parts of their teaching that were relevant to the focus they had defined for their bachelor project, and on return they selected clips for peer analysis; the ownership of this part of the process stayed as suggested by (Harford & MacRuairc, 2008) with the ST. Analysis with codes and categories from the tool (appendix A) were done collaboratively in the workshops, which were facilitated by the researcher. The analyzed video clips eventually formed part of their individual bachelor projects phrased and framed in various ways.

Data were collected as follows: 1) First round of individual interviews carried out immediately after the STs returned to the college following school practice, 2) audio and videotaping of interactions during the collaborative analytical workshops, 3) their bachelor reports (as supplemental data) and 4) second round of interviews at the end of the BEd, after reports had been delivered (table 1).

Table 1: Summary of activities, including data collection.

	The STs bachelor project activities	**Data collection**
November 2009	Four weeks of school practice where the STs individually planned, implemented and videotaped teaching	
December 2009	STs delivered their formulation of a problem-statement.	First interviews
Ultimo December 2009	All STs have one week without formal program for their initial work on the bachelor project. The four STs were facilitated in collaboratively analyzing their video from school practice in full-day workshops during this week	The collaborative analytical workshops were video/audio taped.
March 2010	The STs delivered their project report	Project reports collected
May 2010		Second interviews

Interviews were made based on interview-guides with issue-oriented open questions aimed to reveal each participant's unique experiences (Stake, 1995; Kvale and Brinkmann, 2009). Themes in interview 1 were the STs initial focus in their bachelor project, how they planned the videotaped teaching according to this and their experiences from teaching, and how it related to the bachelor project so far. Themes in interview 2 involved their own free description of hurdles and leaps forward in the process seen in retrospective. This was followed by more structured questions about their outcomes from the collaborative analytical workshops.

RQ1 is answered through a comparison of interview 1 and interview 2, RQ2 by data from interview 2, and RQ3 is supported by analysis of dialogue from the workshop tapes.

Analytical model

To analyze factors influencing teachers' meaning-making is highly complex. This study drew on the interconnected model of professional growth (Clarke and Hollingsworth, 2002) suggesting that change in a teachers' cognition and actions can be identified by analysis referring to four distinct domains and the mediating processes of reflection and enactment connecting them:

- External domain: information, stimulus, and support from external sources;
- Domain of practice: professional experimentation in the classroom;
- Personal domain: teacher's knowledge, beliefs, and attitudes;
- Domain of consequence: salient outcomes.

Clarke and Hollingsworth situate collegial interactions in the change environment surrounding all the domains. This study, with its focus on collaborative video workshops, draws on an adaptation of the Clarke and Hollingsworth model, partly inspired by Van Driel and Beijaard (2003), which includes a domain of collaboration (Nielsen, 2012) - see Fig 1.

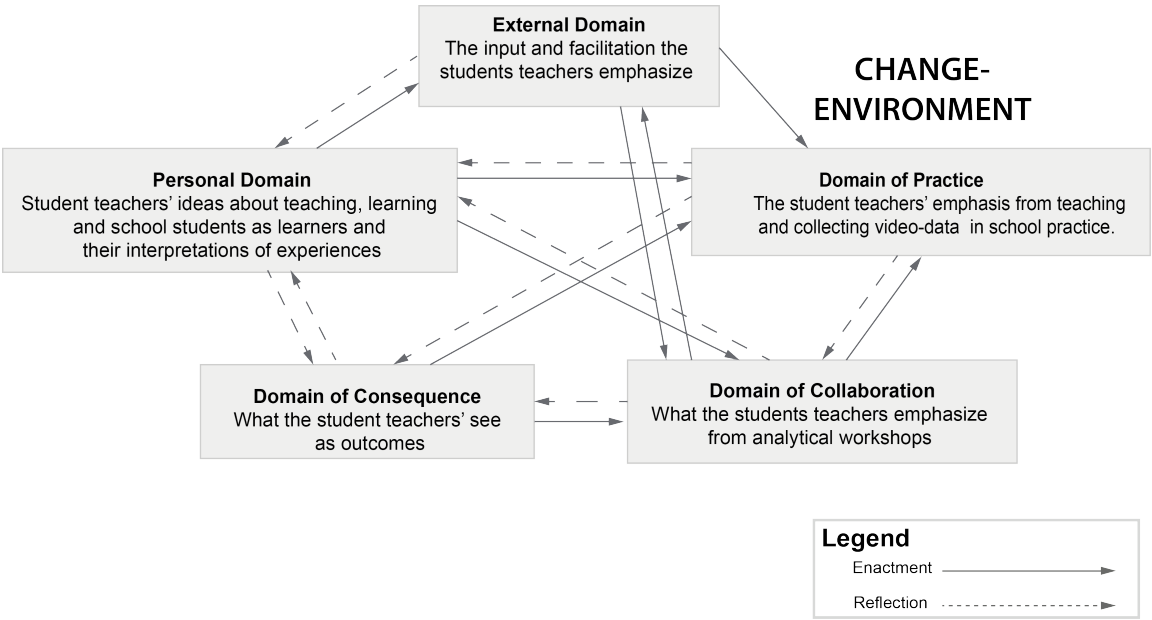

Fig.1: Meaning-making model

The domains are linked by the arrows *reflection* and *enactment* to represent how change in one domain is related to change in another (Clarke & Hollingsworth, 2002). The final representation is called a *meaning-making map*. The map is based on the STs utterances: when a ST's reflection involves two domains a reflection arrow is used between the domains, when the STs refer to how something in one domain entails something in another domain an enactment arrow is used.

Data-Analysis

Interviews were audiotaped and transcribed verbatim with indications of pauses and silences. Quotes used below are translated and used without the indications of the pauses from the original transcriptions in Danish, but marked where words are missing. Analysis of transcripts involved three steps. The meaning-making model provided categories for the initial analysis. In the first step STs' utterances were identified as belonging to the various domains (table 2). It was possible to place all the STs' utterances related to the project in at least one of these domains and a range of utterances were coded as belonging to *more* than one domain.

Table 2: Domains referring to the meaning-making model. Both utterances that were direct answers to interview questions and spontaneous references were included.

Domain	Description
Domain of practice	The student teacher refers to purposefully trying something out in school practice: questions and actions related to their (personal) bachelor inquiry and/or the concrete classroom teaching and the videotaping of classroom-interactions.
Domain of collaboration	The student teacher refers to interactions and dialogues from the analytical workshops related to analysis and discussion of peers' video or to their own video.
Domain of consequence	The student teacher refers to what he/she sees as perceived outcomes: positive outcomes and/or negative experiences, worries and frustrations.
Personal domain	The student teacher refers to interpretations of experience from school practice including ideas about teaching, learning and school students as learners and themselves, or teachers in general, as learners.
External domain	The student teacher refers to input of reading material, research results, tools etc. and to facilitation during the process.

In the second step enactment/reflection was attached to those utterances that in the first step were coded as belonging to more than one domain. For example when Marie in the second interview says: "to present video from your teaching and reflect collaboratively (..) was a learning process", she is referring to domain of practice and domain of collaboration (a reflective arrow) and then to domain of consequence (an outcome). When she says: "To

act in practice and then read theory with new eyes (..) has been really helpful, but also hard because you want to see something related to theory and you cannot always". She is referring to the domain of consequence, and to the personal domain: her interpretations of experiences, and reflections about her own learning. All reflection and enactment codes are described in a codebook[2].

In a third step the content of the utterances in each domain were analyzed using a process of constant comparison to develop open coding categories (Cohen et al, 2007; Glaser and Strauss, 1967). During this process an unrestricted number of subcategories were identified and then, through an iterative process of reducing, merging and synchronizing, these sub-categories were gradually compared and refined to produce the codes. The codes related to the domain of consequence extracted from the full codebook are shown in table 3 as an example.

Video/audiotapes from analytical workshops, and the project reports finished between the two interviews and collected as additional data, enable a broader perspective than the points of view of the individuals, and can be used to triangulate the STs' utterances about experiences and outcomes. The recorded analytical workshops were watched repeatedly and transcribed verbatim. Critical moments were chosen according to the criteria that they related to the issues emphasized by the STs. During the research process it was decided to introduce a focused analysis of the project report with the aim of further illuminating the implications of a particular emphasis of STs, related to T-theory versus t-theory.

Quality Assurance

The double role as facilitator and researcher provided a unique insight into the context. A participant researcher can, as stated by (Cohen et al., 2007, p. 135) support credibility of the findings. It is however important to be aware that a facilitator in collaborative video-analysis may have an influence on the

[2] Available at http://cse.au.dk/en/research-and-development/projects/video-clubs/ and in appendix 5 in the thesis

Table 3: Codes, domain of consequence. Quotes from both first interview (FI) and second interview (SI)

	Code	Quotes
Domain of consequence: Outcomes as ST in relation to the task of making a bachelor project	**T-theory versus t-theory.** Positive outcomes related to taking practice as a starting point before including theory	To act in practice and then read theory with new eyes (..) has been really helpful, but also hard because you want to see something related to theory and you cannot always (Marie SI) This was the first time we studied and analyzed practice and then found the useful theory afterwards (..) it is opposite to the other tasks (Christian SI) I have seen the connection of theory and practice more than before(..) former tasks, at least in pedagogy, have been very theoretical (..)the very philosophical stuff is hard to see in a situation in practice(..) I have developed my project based on video-analysis (..)it was good to have a concrete starting point (..) to realize which theory I could use (Jane SI) It was a jump forward when I read the theory after school practice (..) suddenly I saw how to focus (..) every time I read something I thought (..)what about practice (Louise, SI)
	Structured dialogue. Describe before analyze and interpret	I think it was good that it was a structured dialogue and still a free and open dialogue (..) the big difference between describing, analyzing and interpreting (Marie SI) Focus with a fresh eye on the professional issue in a structured dialogue (Christian, SI) The professional issues, the structured discussions, kept the group together (Jane SI) The new eyes (..) and the professional structured perspective (Louise, SI)
	Collabora-tion Gaining from peer-reflections	My reflections developed by watching the others'(..)observe your own with new eyes (..)to present and (..) reflect collaboratively is (..) a learning process (Marie SI) I used this [contribution from the group] in how I could see (Christian SI) Collaborate (..) to find words for what you have seen (Jane SI) Much I did not see myself (..) perspectives I had a hard time finding myself (..)they managed to ignore me when I tried to explain myself out of a situation (Louise SI)
	Tool for video-analysis.	How to approach and analyze (..) this was the definite leap forward (Marie SI) The hardest part was to analyze the data (..) I used this (..)the tools and models (Christian, SI)
	Mastering making the bachelor project.	Worries: I realize it is very ambitious (..) when I knew it was filmed, I hoped they[the school students] would say something more and better, and I was extremely frustrated just after (Marie FI) I do not know how to focus and what I want to use (Jane FI) Contentment: I knew already when returning from the summer holiday how to arrange it and all agreements with teachers were made (Christian, FI) The bachelor process has been good intense and different (Jane, SI)
	Expected from the college	There are huge differences (..) what the professors want us to do in our project (Jane, SI) I think it has been hard to find out what was actually expected in this task (Louise, SI)
Domain of consequence: Classroom teaching	**Mastering** classroom tea-ching	Worries: They wanted me to stand and talk but when I did so they were noisy(..)I do not master the situation (..)to see what I did myself, it was harder than I imagined (Jane, FI) I think it was really hard to watch my own mistakes (Louise, SI) Contentment: It worked well for me to try to push them, make them do it themselves (Christian FI)
	Continuing learning as a teacher	Reality is unique, to keep this in focus (..) yourself being in a learning process (Marie SI) My results have shown that the kind of teaching you use often(..) you can do something else (..) I am not sure how this will effect my practice I might be more reflective (Christian SI)

participants' interpretation of experiences (Sherin et al, 2009).
In the present collaborative video-analysis the facilitator's role was that of keeping the dialogue structured - description from various angles before interpretation etc. – not to interfere in how the STs finally interpreted the concrete classroom interactions.
The findings may however be biased by the fact that the workshops physically took place at the college and the researcher was seen by the STs as belonging to the college making them emphasize certain constraints more than if the workshops had been situated at for example a placement school. Such bias is hard to avoid. Another type of bias might be blind spots during analysis. To avoid this a fellow researcher not involved in the facilitation participated in data-analysis. Final coding of all interview-transcripts was done independently with an inter-coder reliability of more than 80%. Differences were then compared and discussed until agreement was reached.

Findings and Discussion

STs' interpretations of experiences just after returning from school practice are presented to identify general trends, followed by findings related to how the STs' interpretations appear to develop in retrospect, and their perceived outcomes, represented as meaning-making maps (RQ 1 and 2). These findings that are closely coupled with the data are followed by more interpretative discussions of critical moments from workshop dialogues (RQ3).

STs' interpretations of experiences after school practice

Some trends can be identified in the STs' emphasis when interviewed just after returning to the college. It is evident, for example, that school practice was seen by the STs from two perspectives: mastering the art of becoming a classroom teacher and making inquiries for the bachelor project (Fig. 2).

Marie's teaching in school practice included a session in an 8th grade based on authentic cases from Sudan. Her aim was to inquire into students' development of intercultural competence.

Christian facilitated a group of 8th grade students participating in the robot building competition First Lego League, to examine if it motivated them to learn science.
Jane inquired into students' ability to work with complex concepts related to globalization. Her teaching in a 9th grade class included group discussions about Chinese teenage factory workers.
Louise's aim was to examine 8th grade students' use of scientific concepts in a panel debate about a socio-scientific dilemma.

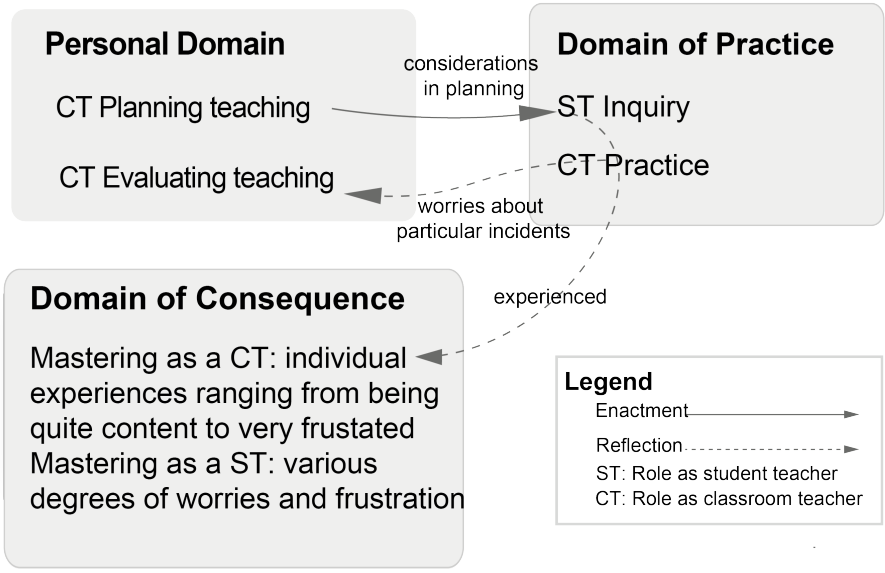

Fig.2: Summing up on the STs interpretations of experiences just after school practice

The STs' interpretations of these classroom experiences differ. Marie and Christian are quite content after school practice. The school students' evaluation of Marie's teaching was positive, the approach with authentic cases had made an impression. She is however worrying about a specific incident - if students in a particular group were off task when she left for another group. Christian finds that in general school students' group-work and his way of scaffolding them went well. In relation to a particular group of three students his gut feeling is that they were good at developing ideas together, though they had different roles and one of them could appear to dominate, but he is not sure how to back the claim about them developing ideas together.

In contrast Jane and Louise were quite frustrated with their teaching experience, Jane in particular. Her students did not engage in the group work and discuss as she had hoped. She had watched the video before interview and was concerned that she may have done too much talking since the students did not seem to engage. Louise also worried about how hard it was for the school students to engage in the role-play and she is surprised how much she corrects and intervenes during their role-play (evidenced by watching the video).
Beside these experiences as a classroom teacher all the four STs worry about how best to approach their bachelor projects. Marie sees her own project as too ambitious and worries about how to focus. She would have liked the video to support theories about development of intercultural competence, but it does not. Jane does not know how to find focus and Christian worries about the concrete analysis.

To sum up - they all refer to incidents from practice and their thoughts about them. These reflections, however, did not lead to any on-the-spot refinements, but appear as emerging thoughts that are then supported by watching the video. Their reflections also seem to become less tacit during the interview. With respect to how they may use this understanding in the future it seems that the focus is not on how to change things in the classroom, as suggested by a range of iterative reflective models (e.g. Oner and Adadan, 2011; Korthagen, 2008), but rather on how the video might be used in the bachelor project.

STs' interpretations of experiences in retrospective

Marie: Marie's meaning-making map is shown in fig 3. She refers to gaining insight into how to analyze the video and the structured approach as the main outcomes (domain of consequence), and emphasizes that it has not been an easy process. She reflects on her own tendency to look for and think in terms of evidence to support theory: "in the situation, when I knew it was filmed, I hoped they [the school students] would say something more and better, and I was extremely frustrated just after." She claims that the collaborative analysis

forced her to reflect on what actually happened, not what is prescribed by theory, and continues: "I wonder if you sometimes use the theories for their own sake, or to understand practice". She refers to the incident mentioned in the first interview and her refined interpretation: that the students apparently were not off-task, just using their personal narratives to relate to the cases from Sudan. She experienced that practice made her read theory with new eyes and (meta)reflects on how you can evolve as a teacher through looking into your own practice.

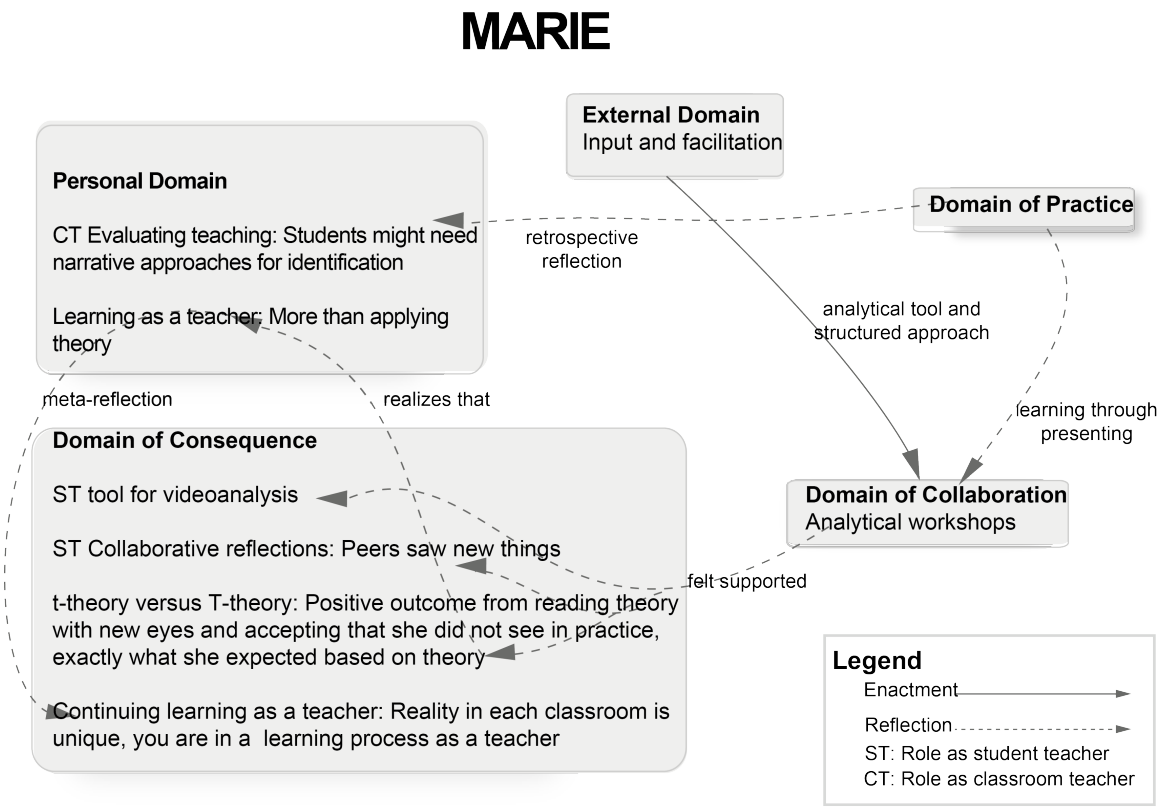

Fig. 3: Meaning-making map Marie

Christian: Christian's meaning-making map is represented in fig. 4. He seems to be the one in the group with the highest confidence in his own ability to manage the task of making the bachelor project. He had already started a course of university study before he decided to switch to teacher education, and he also has experience as a substitute teacher. He describes his own process as positive, progressive and structured, but he experienced to benefit from the collaborative analysis: "The hardest part was to analyze the data (..) I used (..) the tools and models we got".

Furthermore he emphasizes support from the group, that the peers saw additional things. Christian also refers to the incident he worried about in the first interview, how he found indications in the school students' dialogue of them developing ideas together, and like Marie he includes meta-reflection related to learning as a teacher. Finally he states that this was the first time in the four years of teacher education that he had really tried to analyze an experience from practice. The approach in the project during the 3rd year (pedagogy and psychology) had according to him required more-or-less the opposite approach: to examine and discuss theory and from there find practice examples.

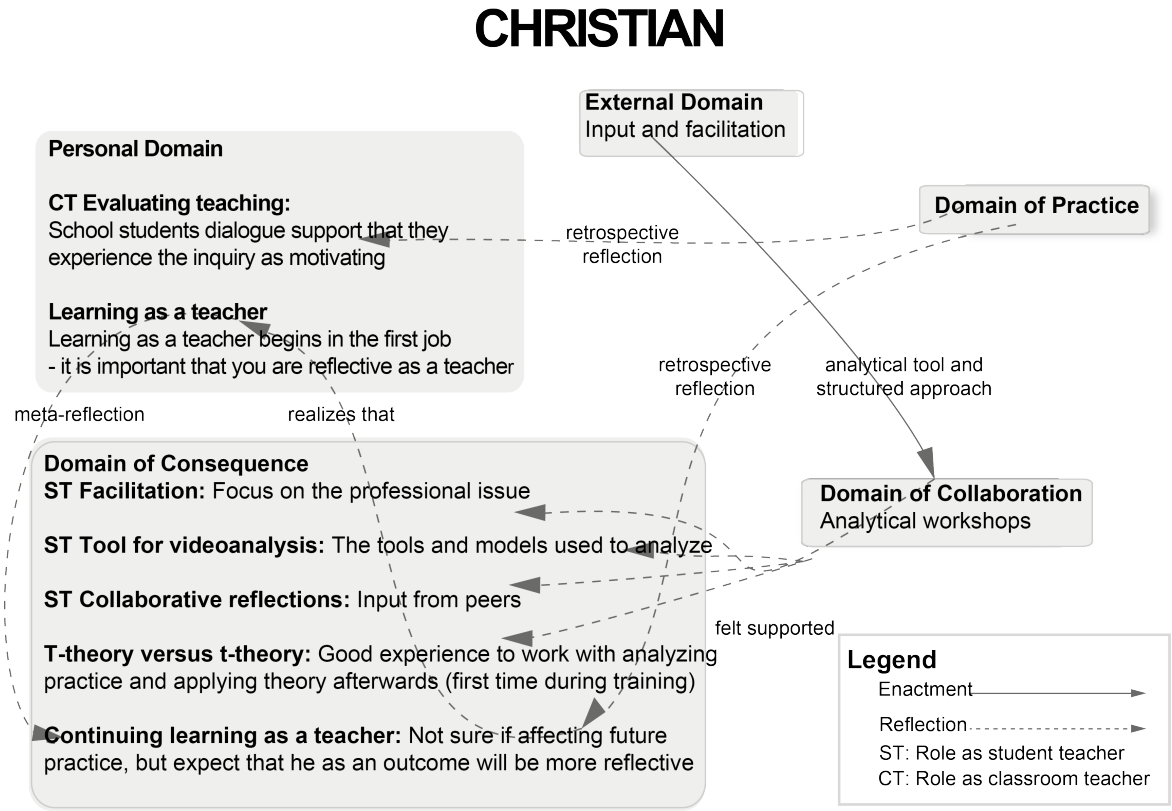

Fig. 4: Meaning-making map Christian

Jane: Jane's meaning making map is represented in fig. 5. In retrospect she describes the bachelor process as very good and intensive, and like Christian she positively highlights outcomes compared to previous tasks, which have been very theoretical. She describes it as a hurdle to connect pedagogical theory and the concrete classroom episodes, but the video-analysis was experienced as a jump forward, as it helped her realize how and what theory

could be meaningful, and she changed her focus based on this. She reflects on how the collaborative analysis of the video and the structured approach in the workshops slowly enabled her develop to describe and understand those experiences that frustrated her so much using her own words. She exemplifies how classroom dialogue, waiting time and communicative approach (Mortimer and Scott, 2003; appendix A) affect school students' discussions and argues about how best to create a classroom environment where students are exploring ideas.

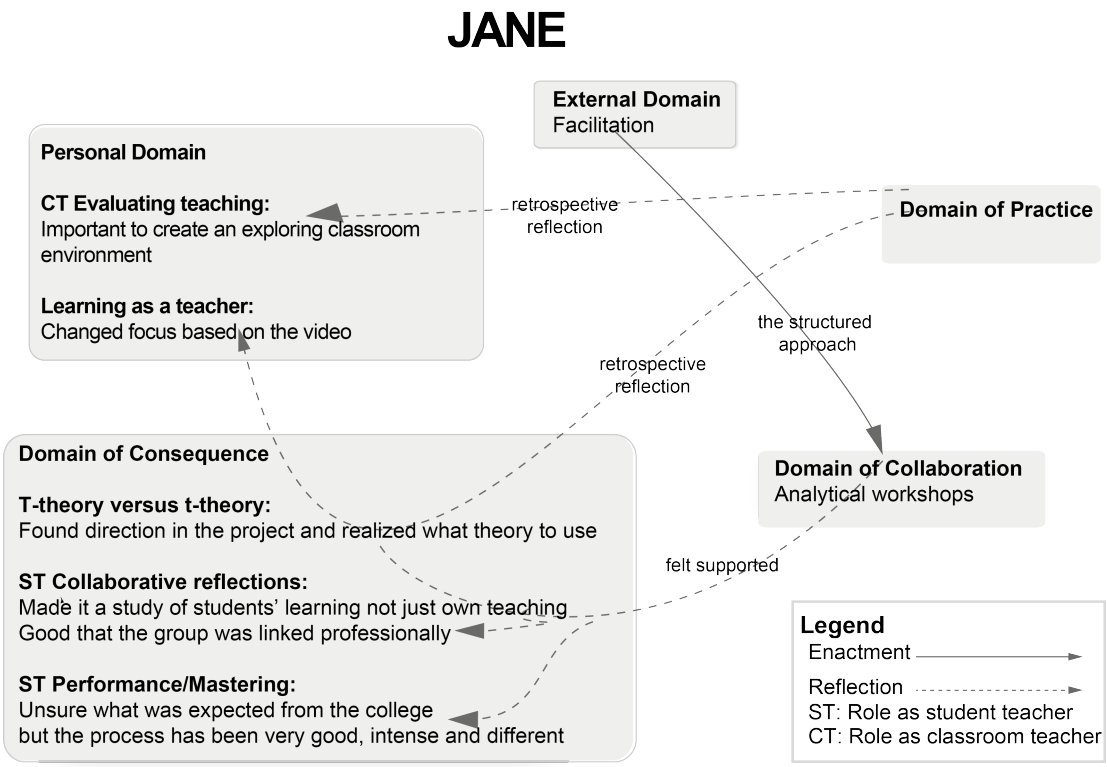

Fig. 5: Meaning-making map Jane

Louise: Louise's meaning-making map is represented in fig. 6. She describes it as a hurdle to get started and gain an overview of what a bachelor project might be, and a jump forward when during post-practice reading she began to focus on theory about students' argumentation - she could 'see' examples from practice while reading. She states that from the start she thought she was going to use the video more than she actually did. Instead she felt that she ended up using examples from practice as in previous tasks at the college. Louise worries more about her classroom teaching at this stage than just after

school practice. She reflects on how the role-play could have been arranged in smaller groups while emotional issues like the students' confidence in presenting in front of the full class seem to be the threshold rather than their ability to use content related argumentation. Furthermore she reflects on an experience of trying to find excuses for herself during the peer discussions: "They managed to ignore me when I tried to explain myself out of a situation". She states that she felt supported from the collaborative analysis. The peers made her look into what actually happened - the perspectives she had problems finding herself.

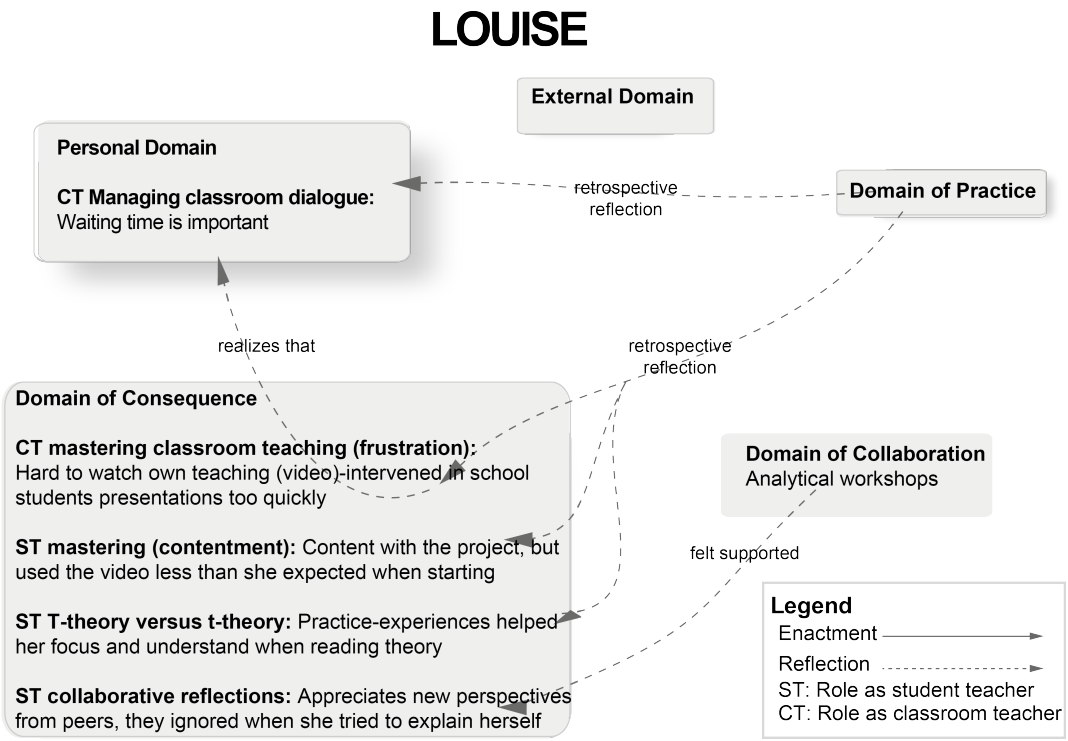

Fig. 6: Meaning-making map Louise

Summing up: In the retrospective interview all the STs refer to incidents also mentioned in the first interview and reevaluate and reconstruct their experiences. The development goes from something partly tacit to them worrying about more specific interpretations of issues that affect students' learning and their motivation to learn. Two of the STs also include meta-reflection about how you learn as a teacher. However when referring to outcomes they do not contextualize those in relation to classroom teaching, but in relation to insights used in their project, for example peers seeing

something new. Beside this the STs emphasize the experience as different from former tasks during teacher education. Their utterances seem to be connected to the T-theory versus t-theory issue: they refer to outcomes from focusing on concrete experiences in school practice, the detailed looking into what actually happened, before applying "theoretical glasses". Bearing in mind that intended learning outcomes in teacher training were changed in 2007 to up-prioritize analysis of concrete practice this implies that the actual practice among teacher educators might not have changed along the intended learning outcomes - at least the four STs have perceived former tasks undertaken as late as the previous year as being a process of using theory as the starting point and then maybe including examples from practice.
After looking into critical moments from the four consecutive workshops below I'll return to this T-theory-t-theory issue which emerged to be important during the iterative process of analyzing the data.

Dialogues during Analytical Workshops

Marie's video: Marie introduces the setting, provides background information and shows around 12 minutes of video. After that the STs share observations. Early in this dialogue Christian refers to and wonders about a particular situation: that the students are very reflective and that one of them refers to Angola. This is the situation emphasized by Marie in the first interview. The video shows how she tries to get a discussion started in a group of students and when she moves on to the other groups the camera stays. The video also shows how she later returns and corrects one of the boys in the group, while, as she explains, it seemed to her that the group discussed terrorism (in Angola) and not the prescribed subject of the lives of young people from Sudan. The situation is not in the workshop pursued instantly, the sharing of observations continues in another direction, but after 10 minutes Marie replays the clip.

Marie [points] I can be a little annoyed at myself, my position, that I am standing between those two good girls, who are very active. It is not consciously, but maybe typically, that you put yourself between two where you expect to get some feedback, instead of placing yourself.

Jane [points] yes

Marie [leans back in the chair fumbling with her hands] yes precisely, between those boys, who are a little harder to motivate to contribute, I have taken up a very safe position right there, I get some feedback, but I would probably get it anyway, I am beginning to realize

The video-clip is replayed once more.

Marie [talks eagerly] I think it is a typical example that the strict scientific information can be hard, as a teacher to put across, but it is as though his story– now I know I am analyzing – it suddenly makes it comprehensible for them, like a story, a narrative in some way

Jane [nods and looks back and forth from video to Marie] yes

Marie when I get back to the group I am a little irritated, because suddenly they are talking about something else, about terrorism, and I didn't see the process then, where they moved from talking about the task and then to talk about the world trade center, almost, but it seems to be their way of actually reflecting on the task, they are not off task as I thought, they are just using another example

Christian [watches Marie intensively] yes

Louise I think they respect him

Marie yes, I think they respect him very much, him who tells, but it is another issue [gesticulate eagerly] they show some knowledge of their own here, an example of something they have heard somewhere, which they suddenly use, to see parallels, to relate to, being young and from Sudan

In this dialogue about the video-clip Marie first refers to her physical position, but after re-watching she seems to realize, that they are actually solving the task. She interrupts Louise, when leading the dialogue in another direction indicating that she experiences this situation as important and that she is just in the process of finding a way to understand it. She talks eagerly and uses categories from the analytical tool (Appendix A): 'scientific versus everyday perspective'.

A range of insights can be drawn from the dialogue. Marie in the interview refers to support from her peers seeing something new. The peers *do* point to issues related to the concrete interaction, but their questions and observations relate to a situation where she already had some worries and this might be her reason to replay the situation. In some ways it is Marie who talks herself into an understanding.

The extract exemplifies the emerging character of the collaborative reflections: something is raised and then later returned to. Marie seems to have a profound wish to understand the situation and with the support of her peers pursue those interactions where she initially worried that something did not work. The extract implies a meaning-making process leading to a new insight. Sherin and van Es (2005) conceptualize with reference to the anthropologist Charles Godwin (1994) teachers' ability to notice and interpret significant features of classroom interactions as their *professional vision*. This can be seen as a concrete example of development of professional vision though a *re-organization and reconstruction of experience* (reflection: Oner and Adadan, 2011, p.480).

Christian's video: In the extract from the workshop where Christian's video is analyzed the group has just moved from observations to working with analysis, when Jane refers to an example of 'student-student uptake' (category from appendix A).

Christian [starts taking notes for the first time during this workshop] This I actually didn't notice before it is growing to be more and more dialogic, there, around these examples of student-student uptake

Jane Could you say, is it that, when they have tried a fair amount of things, several ideas, they have to have some new ideas from one of the others to move on [Christian takes notes]

Marie though they are different, they feel that none of them dominates, and I agree from watching [the video], and I think this is very important

Christian yes, none of them dominates

Marie no, and in that way, it is not negative that they have the different roles

Christian [takes notes] no, it has also been my experience, that maybe one of them takes the lead, but not in a dominating way, and this can be an advantage

Jane I agree, it does not seem to be a problem in the group

Christian no, this is right and they knew this afterwards, they said it in the interview, it is interesting, they had experienced this synergy themselves, what they had learned was that they gained from working together, they could solve the task better, they could not do it alone

Christian, like Marie, seems to talk himself into an understanding with help from the peers. He mentioned his worries about the group of school students

being very diverse in the first interview. The observation from a peer during the analytical workshop, that pointed to something that was already on his mind, related to an analytical category, seems to lead him on in his interpretation of the interplay in the group: professional vision.
The key to understanding his meaning-making might be that he is highly motivated to work autonomously with an inquiry into practice, and that he realizes when there is something from the dialogue he can use in his individual process of learning from experience. Noticeably during the interview he refers to this being the first time during teacher education that he really got this chance and was supported to inquire into practice.

Jane's video: The first part of the extract where Jane's video is analyzed is from the start of the workshop. The clips she presents are related to her frustration after school practice: problems with classroom management and school students' lack of engagement.

Christian [looks at Jane] I noticed that only four guys and one girl said something
Jane [moves around on the chair] there were two girls but the other one [hard to hear what she says]
Christian mmm, I just didn't notice her, I was just to trying to count how many of them had said something at all
Jane mmm, this is right
Louise but I noticed, there was a lot of student input and uptake from students, you catch what they say and repeat it [an example from the video where Jane asks a certain question] but you are fishing a little
Jane yes – a lot
Christian it is to some degree an authoritative approach
Jane [looks down and puts her hand half in front of her face] yes that is correct
Christian but, but, once again is it that you as a teacher often feel forced to stand up in front of the students, it gives another position, this you cannot avoid
Jane mm, I would have liked them to discuss more, and I can hear it now, when I see it, that I do not always give them time to answer the questions I pose, I actually do most of the talking myself, and it doesn't give them the possibility to talk very much
Christian It actually seems that this class needs a veritable kick in the ass, I mean, if they do not have a teacher who pushes them like you do, I think they would learn even less than in this situation
Jane we actually talked about, that it is like that, this class, that it is really impossible

The STs continuously use the vision term 'notice' and refer to the challenges in the class. Christian uses the term 'an authoritative approach' and other categories from the analytical tool are also used. The peers are quite gentle ("this you cannot avoid" etc.) yet Jane sees the point: "I can hear it now when I see it". The situation is first attributed to the class being hard to handle. Later in the workshop, during analysis, the situation is raised again.

Louise I think it could be described as an interactive authoritative method[3]
Facilitator You can always discuss this type of question, IRE, in relation to the learning goals, if this is the right approach
Jane but as I see it, it probably is not

The emerging character of the reflections is again evident. When seeing the dialogue also in the perspective of the two interviews Jane, in contrast to Marie and Christian, has clear problems with classroom management. She can be seen as the one taking the greatest step forward challenging herself on her weakest points, and using exactly those clips she knew were critical in relation to her own teacher-role. During the dialogue she is funneling them into a growing understanding of the school students' potential learning connected to her own extended use of triadic dialogue, lack of waiting time etc.: why they might not really discuss the issues she wants them to discuss.

Louise's video: The extract from the workshop with Louise's video-clips provides an insight into her reference to finding excuses for herself and the school students. After Louise has presented the context, the reason for choosing role-play etc. she shows a video-clip with a group of school students doing a role-play framed as a panel debate and before the peers contribute with observations Louise explains about a particular boy in the class.

Louise Just a little comment, there is this boy called [his name], he is hyperactive and has this tendency to sing and flute during the lesson, you have to clamp down on this as a teacher, furthermore he loves drinking sugar ice tea and this makes it worse so this is why I correct him as I do

The peers start sharing their observations, but the dialogue is for a period outlined as one comment from a peer and then an answer from Louise trying to explain, for example when Jane contributes with an observation about a particular girl.

Jane If you are not strong in you arguments she appears to be very hard to argue against and very

Louise yes, but everybody in the class likes her, she does not hurt anyone, but she might have an attitude

During the continuing sharing of observations this continues.

Jane [gesticulates] are you not a bit controlling, related to the goal of them arguing or maybe it is just me, but you pose a lot of questions, they were expected to argue in the panel, but you interrupt several times to lead

Louise yeah we had discussed it before the lesson that this was the first time, they had not tried to make a panel debate or role-play before so..., they had not tried it in social science or Danish or anything

Christian this problem that they raise with many more male than female [refers to population pyramid] it seems that they cannot really discuss reasons and consequences

Louise I think the problem is that [the named boy] disturbs, he is very very disturbing that day

During analysis there are, like in the other extracts above, examples of the use of a variety of analytical categories

Christian I think, isn't it, interactive authoritative, because it is still authoritative, it is a closed task, but still I find it hard to place

Marie in the start they depend very much on you, but then you pose some, you pose the right questions

Christian It would have been easier if the students were more equal

Through the workshop Louise first seems to experience the observations from the peers as an attack on the students she had grown to know and be fond of; none of the peers explicate this, but Louise also does this herself while summing up and being self-reflective on the challenges in the classroom and when expressing a new insight into the dynamics of the communication

Louise When analyzing my own clips I think that these are so sweet students but when you are watching you do not know, of course, whether these are sweet students or not, and then I have such a clip with [the named boy] I think this clip is bad because nothing serious is happening and I first thought it was [the named boy] but in reality it might not be him, it might be the dynamics in the communication

Summing up: All the STs emphasize outcomes related to the collaboratively analysis, and in the case of each participant the workshop dialogues have facilitated them in considering critical moments, and exemplified 1) a process where they talk themselves into an understanding of incidents worrying them (to some degree tacit) and 2) how they use the inputs from the peers and the analytical categories during this process including the emerging character of the reflections. *But* during the iterative research process, which shifted between analyzing interviews and these workshop dialogues, it became apparent that even though the STs were conscious of the outcomes from collaborative analysis and began to use this new insight in their interpretations regarding the classroom teaching, they were *not* always framing their outcomes in relation to the classroom incidents. This inspired a focused analysis of their project reports to further illuminate this paradox, and examine if and how the structured approach, the analytical tool and a t-theory approach, which they emphasize, have influenced their reports.

The bachelor reports

Marie presents the analyzed video clips under the headlines: description, analysis and interpretation used to structure the workshops, in her report. She uses categories such as teacher questions, communicative approaches, and taxonomic levels from the tool (appendix A). This way of using theory related to situational knowledge is like t-theory. However the report starts with many general abstractions about cultural meetings, globalization and 'Bildung' in students' work with epochal key problems (Westbury, Hopmann and Riquarts, 2000). Although not all of this T-theory is included in discussions. Christian in his report refers to the analytical tool and uses the categories teacher-student and student-student dialogue: types of questions, uptake, high-level evaluation and everyday versus scientific perspective (appendix A).

The theoretical framing in his report involves theory related to the analytical tool and some general abstractions (T-theory) related to motivation, not all, but most of it later referred to in his discussion.
Jane also uses the categories from the analytical tool to analyze the situations she worried about and uses description, analysis and interpretation to frame this like Marie. In the theoretical front section the t-theory used in her analysis is supplemented with general abstractions about Bildung (Westbury et al., 2000); this is not referred to in the later discussion.
When looking into Louise's project report it is confirmed that the video-data is used as examples as she states it herself. She presents and discusses an argumentation model and uses the selected clips discussed in the workshops to exemplify.

It is remarkable that all of the STs prioritize large grain size T-theory. This is not a normative evaluation of what makes a good bachelor project, just stating that there seems to be a contradiction between what they say and what they do. They spontaneously criticize former tasks at college as too much T-theory and emphasize outcomes from starting with analyzing practice, but still in their reports they prioritize describing certain T-theories beside the analysis of the concrete experiences. Maries seems to be aware of this contradiction when in the second interview she reflects on using theories for their own sake rather than for deepening understanding of practice. All the four bachelor projects were actually well evaluated (A or B) and it might be that the STs emphasize outcomes and feel they learn from using structured analysis to understand concrete classroom interactions, but at the same time they want to perform as STs, and they presumably believe that reference to those specific general abstractions is important to get the good grades. Jane is the one most critical of the T-theory approach in college and the one who most specifically emphasizes gaining from a different approach, so we will let her have the final word on this subject: "former tasks, at least in pedagogy, have been very theoretical (..) the very philosophical stuff is hard to see in a situation in practice(..) I have developed my project based on video-analysis (..) it was good to have a concrete starting point (..) helped me to realize which theory I could use".

Conclusions and Perspectives

The STs interpretations of their classroom experiences develop from just after school practice to reflecting in retrospective. It is evident that some of them move further and think about wider implications also in relation to their own continual learning. But the structured collaborative analysis of concrete classroom interactions appears to support each of them in reconstructing experiences from school practice and focus selective attention on particular aspects of a concrete incident including teacher-student and student-student interactions, and students' learning.

This is however not a straightforward process. Both the structured approach, the analytical categories and input from peers seem to influence the individuals' meaning-making: evident both in their perceived outcomes, their negotiation of meaning during workshops, and in their use of these inputs in project reports. They seem to *develop competencies to interpret the affordances of particular situations* (teachers' learning, Edwards, 2002), and the emerging character of this development is characteristic, as Jane says: " I slowly developed my own way of describing and understanding those experiences that frustrated me so much". But their reflections are not so much about *how to change their teaching accordingly* (teachers' learning continued, Edwards, 2002). In stead they emphasize outcomes related to making their projects, such as their peers' contributions helping them to focus. Each of the STs acknowledges being in a learning process, for some of them this is a hard process, and they spontaneously and positively refer to starting with concrete experiences in school practice before applying theory. But when structuring their final report they seem to write in a way they think their college tutors expect. In spite of refined learning outcomes to up-prioritize analysis of practice it still seems that the STs navigate in two parallel worlds, the field-world and the college world, and this they solve pragmatically; so to speak they put an icing of T-theory on the top of their informed analysis, their belief being that they need the T-theory to perform at the college.

The findings can occasion cautious optimism in relation to STs gaining from new sorts of tasks in pre-service teacher education, but if the aim is for STs to

acquire competencies in continuous learning in and from practice, then better alignment between intended learning outcomes, types of tasks and evaluation of them (Biggs and Tang, 2007) is needed. This dilemma could be solved for example through iterative tasks that emphasize new trials in school practice based on the first analysis, and by not grading reports from the peer-analysis of school practice video (e.g. Harford and MacRuairc, 2008). But STs, like most students, probably see what is graded as the important part of their education, and an evaluation of final presentations at a conference with peers, in-service teachers and college professors might be one of the possibilities to better situate the STs' findings in a school context aligned to the refined intended learning outcomes.

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Apppendix A

Categories and codes used in the workshops to analyze video from student teachers' school practice. Codes in the three main categories: Students, teacher and approach to subject matter are extracted from a full codebook for analysis of interactions in science classrooms (Andersen and Nielsen, 2011). Three various taxonomies of educational objectives were additionally referred to: Blooms taxonomy with cognitive domains, Krathwohls taxonomy of affective domains and the SOLO taxonomy (Krathwohl, 2002; Biggs and Tang, 2007).

Category	**Codes**		**Description of code**
Students	Students' engage-ment	Substantial engage-ment	When students are "doing science": construction, representation and evaluation of knowledge claims and investigative methods, showing that students are involved with academic content and issue.
		Procedural display	When students are "doing school": when the talk is about rules and regulations, homework assignments, lengths of thesis etc.
		Off task	When students do not work with and/or talk about the task
	Students' communi-cation	Generating ideas	When a student introduces own ideas about science into discussion in class or in group-work. The science ideas don't have to be canonically right. Is not used when students directly refer to formulation in textbooks or other canonical material.
		Uptake of peers' ideas	When students incorporate words or directly refer to utterances from other students.
		Overruling peers	When students directly tell peers to shut up, or imply that what they say is not relevant directly or indirectly by not listening.
		Easy solutions and shortcuts	When students' talk or actions directly indicate that they are taking a short cut to complete the task quickly.
Teacher	Teacher's questions and responses	Closed questions	A question with one correct answer. A question where the teacher already knows the answer and asks to hear if the student knows the answer.
		Authentic questions	A question that can be answered in various ways. A question not asked to elicit one single pre-specified answer but includes a request for information. Open-ended questions with indeterminate answers are a sub-set of authentic but not all authentic questions have to be open-ended.
		Formative feedback	When students get feedback focusing on their further development and learning process.

		Teacher's uptake	Is used when teacher is incorporating a part of a student's previous answer in their subsequent question or answer.
Approach to subject matter	Content perspective	Everyday perspective	Problem raised in a everyday context
		Scientific perspective	Problem raised in a scientific context
	Commu-nicative approach (Mortimer and Scott, 2003)	Authorita-tive interactive	The teacher leads students through a sequence of questions and answers with the aim of reaching one specific point of view.
		Authorita-tive – non interactive	The teacher presents one specific point of view
		Dialogic - interactive	The teacher and students explore ideas, generate new meanings, pose genuine questions, listen to and include different perspectives.
		Dialogic - non interactive	The teacher considers various points of view, presents and explores different perspectives.

Appendix 4

Paper IV

Nielsen, B.L. (2012). Naturfagslæreres konstruktion af forståelse og fortolkning af erfaringer i den første praksis. *MONA 2012*(2), 37-54

Naturfagslæreres konstruktion af forståelse og fortolkning af erfaring i den første praksis

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Abstract: *Baseret på cases fra to nye naturfagslærere, repræsenteret ved brug af en "meaning-making-model", er en række muligheder og udfordringer for fortsat læring i praksis identificeret. Til perspektivering inddrages refleksioner fra en kohorteundersøgelse af naturfagslærere. Muligheder diskuteres under to overskrifter: 1) at lære ved at afprøve i praksis og 2) at lære i kollegialt samspil. Udfordringer ift. pkt. 1 identificeres relateret til om lærerne fokuserer på elevernes naturfaglige begrebsudvikling, eller om det eneste succeskriterium er glade og aktive elever. Udfordringer ift. pkt. 2 er først og fremmest store forskelle fra skoler hvor hver naturfagslærer passer sit, til skoler med tæt samarbejde.*

Indledning

Naturfagslæreres professionelle udvikling gennem læreruddannelsen og deres fortsatte læring ude i praksis er gennem de seneste år blevet et centralt tema inden for naturfagsdidaktikken. Naturfagslæreren ses som den afgørende nøgle til at kvalificere elevernes læring, og især fremhæves lærerens kompetence til fortsat at lære af og i praksis (Osborne, Simons & Collins, 2003; Feinam-Nemser, 2001). Danske og internationale undersøgelser peger på at de første år i praksis er særlig sårbare (fx Ellebæk & Evans, 2005), og forskellige tiltag med mentorordninger og lignende er iværksat lokalt. De resultater der præsenteres her, handler ikke om et specifikt tiltag, men om hvordan nye naturfagslærere selv forstår og fortolker deres erfaringer, hvilke situationer de peger på, hvor de udvikler sig professionelt, og hvad det indikerer af udfordringer og muligheder. I de seneste år er der på de danske University Colleges (UC) blevet uddannet færre og færre lærere med naturfaglige linjefag, så der er et stort behov for at fastholde naturfagslærere og støtte dem i deres løbende professionelle udvikling (Følgegruppen, 2012). Derfor er der brug for mere viden om nye naturfagslæreres erfaringer. I forbindelse med andre undersøgelser har jeg dels fulgt

en gruppe lærerstuderende med naturfaglige linjefag i forbindelse med videoundersøgelser til deres bacheloropgaver, dels set på refleksioner over kommende praksis som naturfagslærer fra en kohorte af dimittender (Nielsen, 2011). Det er derfor oplagt at følge lærerne fra disse undersøgelser i deres første praksis, men før jeg beskriver dette nærmere, en kort opsummering af hvad vi ved fra forskningen om (naturfags) læreres professionelle læring.

Hvad ved vi om (naturfags)læreres læring?

Undervisning i naturfag, herunder organisering af elevernes undersøgende aktiviteter, er et komplekst foretagende der erfaringsmæssigt stiller store krav til lærernes faglige og pædagogiske kompetence (Fishman, Marx, Best & Tal, 2003). Der har derfor været fokus på naturfagslæreres viden og kompetence både i international forskning og i lokalt dansk udviklingsarbejde. Fx er pedagogical content knowledge (PCK) anvendt til at indkredse den syntese af fag-faglig og fagdidaktisk kompetence med indsigt i skolekonteksten som ser ud til at kendetegne læreres særlige faglighed (Shulman, 1986; Abell, 2007; Berry, Loughran & van Driel, 2008). Lærerne må forventes at have et vist niveau af PCK med fra læreruddannelsen i relation til en række faglige temaer som de har arbejdet med og afprøvet i praktikperioder. Dette er afsæt for fortsat læring i praksis uformelt i hverdagen eller gennem deltagelse i mere formelle aktiviteter. Eraut (2004) identificerer fire typiske læringsaktiviteter på en arbejdsplads: 1) deltage i teamsamarbejde, 2) arbejde side om side med andre, 3) tackle udfordrende opgaver og 4) arbejde med klienter. Tynjälä (2008) identificerer lignende typer af aktiviteter: læring gennem at 1) gøre arbejdet, 2) samarbejde og interagere med kolleger, 3) arbejde med klienter, 4) tackle nye og udfordrende opgaver, 5) reflektere over arbejderfaringer, 6) deltage i efteruddannelse og 7) gå i gang med nye arbejdsområder. Når det specifikt gælder lærere, ved man noget om hvad erfarne lærere selv peger på, men ikke så meget om novicerne. Erfarne læreres egne cases med læring i praksis handler typisk om refleksion over egen praksis, herunder at eksperimentere (afprøve noget bevidst) og at blive inspireret af kolleger (Bakkenes, Vermunt & Wubbels, 2010).

Uformel og formel læring kan ses i et kontinuum hvor episoder og samspil i hverdagen spiller sammen med intentionelle professionelle læringsaktiviteter (Eraut, 2004). Når det gælder formel efteruddannelse, er der en stigende konsensus fra forskningen om at kollektiv deltagelse i længere forløb med fagspecifikt fokus og undersøgelse af elevernes læreprocesser lokalt er centrale elementer (Desimone, 2009). I en sociokulturel forståelsesramme må læreres læring således ses som situeret, medieret og distribueret, som en løbende proces der både handler om en ændring i viden og holdninger til undervisning i naturfag og om handlinger i klasserummet og i samarbejde med kolleger (Borko, 2004). Nogle forskere har endvidere peget på et feedbackloop

via lærerens fortolkning af elevernes reaktioner (Fishman et al., 2003). Hvis man som lærer fx prøver modeller fra "kooperativ læring" og oplever at eleverne er motiverede og engagerede, er det naturligt at blive ved med at udvikle undervisningen i den retning. Lærernes *meningskonstruktion*, deres situerede konstruktion af forståelse og fortolkning af erfaring, kan altså ses som nøglen til at forstå deres læreprocesser (Wertsch, 1991; Edwards, 2001; Nichols, 1997; Ebenezer, 1995).

Forskningsspørgsmålene bliver på denne baggrund:

- Hvad er det for erfaringer og læringssituationer fra den første praksis nye naturfagslærere fremhæver?
- Hvilke muligheder og udfordringer for fortsat læring i praksis kan indkredses baseret på disse?

Undersøgelsens design og metode

Denne undersøgelse er designet med et pragmatisk miks af metoder (Newby, 2010).

Nye naturfagslæreres meningskonstruktion må som udgangspunkt forstås ind i den skolevirkelighed de bliver en del af, hvor en hel række faktorer kan spille ind på de udfordringer og muligheder de oplever. Case og interviewundersøgelse af et mindre antal lærere kan bidrage med en dybere forståelse af sådanne komplekse samspil. Her anvendes interview med to naturfagslærere der er i gang med deres andet år i praksis, som de centrale data. For at perspektivere disse to læreres erfaringer anvendes som supplerende data en opfølgning på en kohorteundersøgelse med en årgang af naturfagslærere fra en større læreruddannelse. Som dimittender forudså mange af dem særlige udfordringer ved at skulle undervise i naturfag (Nielsen, 2011). Er de kommet til at undervise i naturfag, og hvilke erfaringer fremhæver de der er? Hvordan ser de udfordringer og muligheder som identificeres ved casestudierne, ud i dette bredere perspektiv? Først lidt om denne kohorteundersøgelse, og derefter vender jeg tilbage til interviewundersøgelsen.

Kohorteundersøgelsen

Første runde af kohorteundersøgelsen (n = 87) blev gennemført i juni 2009 lige inden dimission og var baseret på dimittendernes refleksion over sig selv som fremtidige naturfagslærere og over konkrete cases fra naturfagsundervisning. Resultaterne viste at mange af deltagerne forudså store faglige udfordringer ved at undervise i de dele af naturfag der har fysik- og kemifagligt indhold. Derudover indikerede svarene en grundlæggende elevcentreret tænkning, med fokus på elevernes engagement og deres aktiviteter, ikke det afsæt i lærerens transmission af et givent stof som diskuteres i en del international forskning hvor deltagerne er lærere fra gymnasialt niveau (fx Tsai, 2002). De UC-uddannede naturfagslæreres overvejelser om elevernes aktivi-

teter har dog sjældent fokus på hvad og hvordan eleverne lærer naturfag gennem aktiviteterne; overvejelser om hands-on-naturfag bliver ikke så ofte koblet med et minds-on (Nielsen, 2011).

Anden runde af kohorteundersøgelsen, de data der anvendes her, er fra december 2010/januar 2011 hvor lærerne var i gang med andet år i praksis. Genbesvarelsen var på 66 %. "Ikkesvar" er jævnt fordelt på linjefag og køn, men lærere der ikke underviser, kan være underrepræsenteret pga. udlandsrejse eller andet. Derudover må det understreges at det er én kohorte fra ét læreruddannelsessted, og at resultaterne ikke nødvendigvis viser et landsdækkende billede. Spørgeskemaet har hovedsageligt anvendt åbne svarkategorier, med opfordring til refleksioner over eksempler fra egen naturfagsundervisning – noget der har været vellykket/mindre vellykket. Dataanalyse har bestået af databaseret kategorisering af lærernes refleksioner.

Interviewundersøgelse

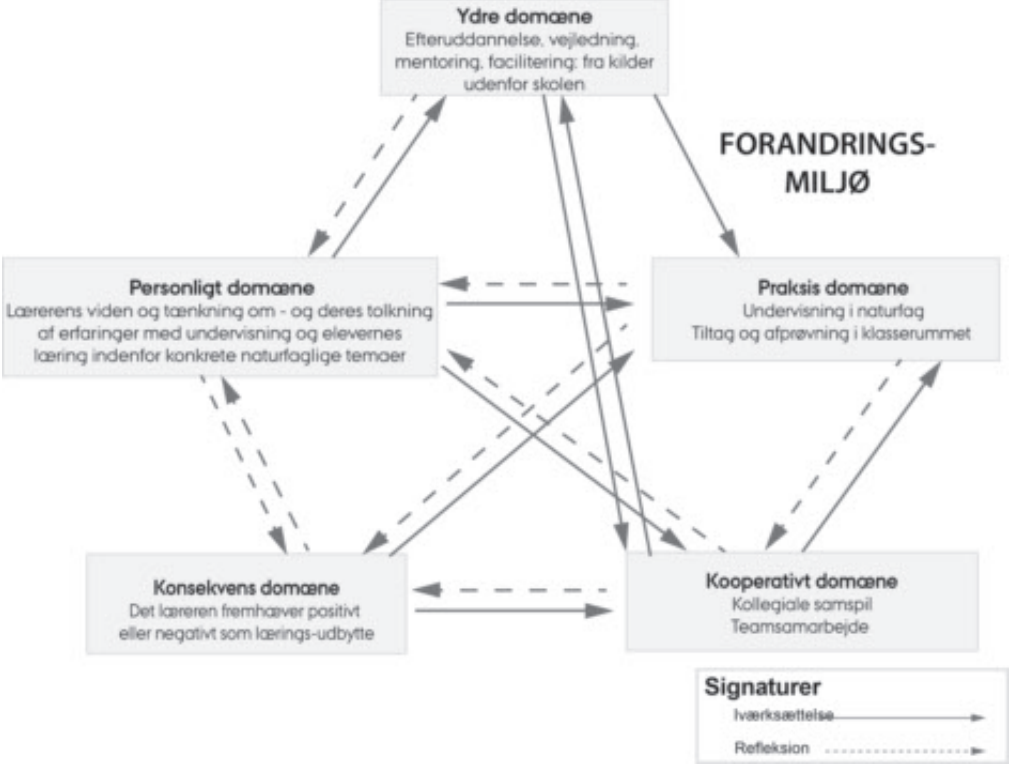
Som nævnt er de primære data interview med to lærere som her kaldes Jane og Christian. De to er valgt fra en gruppe på fire der blev fulgt i forbindelse med undersøgelser til deres bacheloropgaver. De er valgt fordi de begge har en del naturfag på skemaet, men med reference til første runde af kohorteundersøgelsen kan de siges at repræsentere markante forskelle i baggrund for at komme til at undervise i naturfag. De to andre fra gruppen kom hhv. til kun at undervise få timer i et enkelt naturfag og til at arbejde på en højskole. Det sidste interview med Jane og Christian er fra deres andet år i praksis ligesom anden runde af kohorteundersøgelsen. Christian har linjefag i fysik/kemi og biologi og underviser både i disse fag, i geografi og i natur/teknik på mellemtrinnet. Jane har linjefag i geografi og har haft flere hold i dette fag begge år, men har på andet år også fået natur/teknik. Christian har højniveau i naturfag fra gymnasiet inden læreruddannelsen, to naturfaglige linjefag og særlig identitet som naturfagslærer. Janes baggrund er det interdisciplinære fag geografi og en bredere læreridentitet. Hun udtrykte fra sidste år på læreruddannelsen interesse for at komme til at undervise i natur/teknik, som alle lærere med naturfaglige linjefag i princippet har kompetence til, men gav også udtryk for fag-faglig usikkerhed.

Interviewene med de to lærere har været semistrukturerede (Kvale & Brinkmann, 2009), med opfordring til at fortælle om konkrete episoder hvor de har oplevet at udvikle sig professionelt. I erkendelsen af at dét at episoder huskes, er påvirket af mange faktorer, fx at usædvanlige hændelser huskes bedre end hverdagshandlinger (Eraut, 2004), er der fulgt op med supplerende spørgsmål om evt. efteruddannelse, om deres samarbejde med kollegerne, om hvordan de anvender det de har med fra læreruddannelsen, og om deres tilrettelæggelse af den daglige undervisning.

Interviewene er analyseret via kategorisering og kodning med afsæt i et antal overordnede domæner i en analysemodel (figur 1).

Analysemodel

Analysemodellen er videreudviklet fra den såkaldte Interconnected Model of Professional Growth (Clarke & Hollingsworth, 2002). Clarke & Hollingsworth gør op med professionel udvikling som noget andre tilbyder lærere, og med et simpelt årsag-virknings-forhold hvor man tænker at input udefra tilfører lærerne ny viden der får dem til at ændre på undervisningen med den ønskede kvalificering af elevernes læring som resultat. Lærerne ses i stedet som aktive agenter i en løbende læringsproces (Clarke & Hollingsworth, 2002). De identificerer på baggrund af empiriske undersøgelser fire domæner relateret til professionel læring. Det femte domæne, det kooperative domæne (figur 1), er tilføjet i min tilpasning af modellen der også med brugen af formuleringer der peger mod PCK i det personlige domæne, er delvist inspireret af van Driel og Beijaard (2003). Oprindeligt er de kollegiale samspil af Clarke & Hollingsworth placeret i det omgivende forandringsmiljø, men med den stigende erkendelse af betydningen af professionelle læringsfællesskaber (McLaughlin & Talbert, 2006) og en del efteruddannelse hvor input fra ydre domæne organiseres i forhold til faggrupper, har jeg haft brug for dette domæne i mit arbejde med modellen.



Figur 1. *Analysemodel tilpasset fra The Interconnected Model of Professional Growth (Clarke & Hollingsworth, 2002).*

De to typer af medierende processer, refleksion og det at sætte noget i værk (enactment), ser jeg som en særlig styrke ved modellen. Refleksions- og iværksættelsespilene repræsenterer måder hvorpå forandring i ét domæne hænger sammen med forandring i et andet[1]. Det fremhæves at "enactment" i modsætning til bare "acting" anvendes for at identificere en bevidst iværksættelse af nye tiltag baseret på hvad læreren ved, tror på eller har erfaret (Clarke & Hollingsworth, 2002). Handling alene, fx i klasserummet, skal ses inden for rammerne af praksisdomænet. Jeg vil desuden fremhæve konsekvensdomænet som giver plads til at det lærerne værdsætter eller absolut ikke værdsætter, inddrages som en vigtig dynamik i forbindelse med deres professionelle udvikling. Dette er i overensstemmelse med det feedbackloop fra læreres fortolkning af elevers reaktion på forandring til deres fortsatte iværksættelse af nye tiltag som er nævnt ovenfor med reference til Fishman et al. (2003).

Analyse af interview

Analysen er sket i to trin. Først er de domæner hvor lærernes udtalelser hører til, identificeret. Her kan en udtalelse kodes som hørende til mere end ét domæne.

I trin 2 er de udtalelser der hører til mere end ét domæne, kodet med enten refleksions- eller iværksættelsespil. Clarke & Hollingsworth kalder deres repræsentationer for "change sequences" eller "growth networks" hvis det fortolkes som mere blivende forandringer. I min brug af modellen til at repræsentere læreres meningskonstruktion kalder jeg dem for "meaning-making maps".

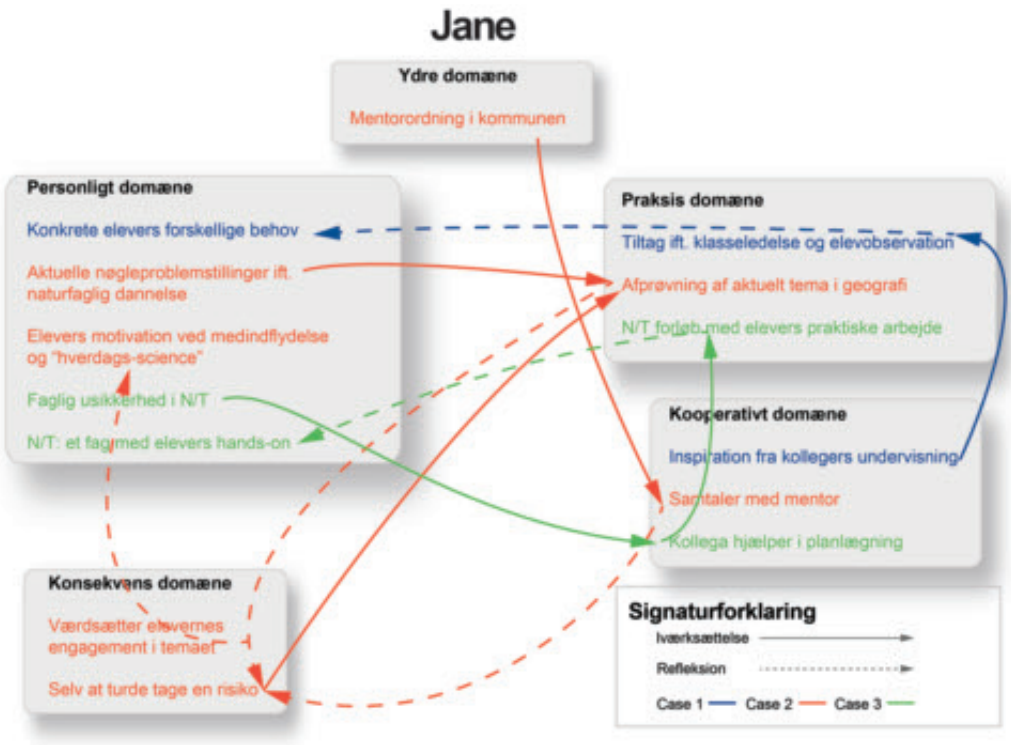
Resultater: Jane og Christian

Jeg vil starte med Jane og Christian: tre episoder de hver især spontant fremhæver, repræsenteret som meaning-making maps. Derefter vil jeg inddrage resultater fra kohorteundersøgelsen og bruge disse i diskussion og perspektivering.

Jane

De tre læringssituationer som Jane fremhæver, er repræsenteret i figur 2. Den første case handler om at hun det første år fik mulighed for at overvære nogle kollegers undervisning af egne elever (blå i figur 2). Det inspirerede hende til nye tiltag i hendes egen klasseledelse, og observation af eleverne i situationer hvor hun ikke selv var på, gav mulighed for at fokusere på hvordan forskellige elever bedst kunne tackles og støttes.

1 Kodebog med beskrivelse og eksemplificering af alle medierende pile kan findes på www.cse.au.dk/videoclubs (lokaliseret den 10. april 2012).



Figur 2. *Meaning-making map: Jane.*

Den anden case handler specifikt om geografiundervisning (rød i figur 2). Hun refererer til linjefagsforløbet fra læreruddannelsen og at hun havde gået med overvejelser om hvordan hun kunne arbejde med aktuelle nøgleproblemstillinger. I forbindelse med jordskælv og tsunami ved Fukushimaværket i Japan kastede hun sig ud i det, opildnet af elevernes mange spørgsmål. Hun oplevede nogle meget engagerede elever og reflekterer over elevernes motivation og betydningen af at de har medbestemmelse, og at det naturfaglige handler om noget der omtales i pressen. Derudover fremhæver hun sin tilfredshed ved at turde tage en risiko og bryde sit behov for kontrol og detaljeret planlægning. Hun delte den positive oplevelse med den mentor hun har på skolen da kommunen har besluttet en mentorordning for nye lærere. Han støttede hende i fortsat at udfordre sig selv, så hun har videreudviklet dette område.

Jane fortsætter med at henvise til kollegernes betydning i den tredje case (grøn i figur 2). Hun var meget usikker da hun skulle i gang med at undervise i natur/teknik – det gik op for hende at hun ikke havde et repertoire og faglig indsigt på samme måde som i geografi. Hun endte med lidt desperat at bede en kollega om hjælp. De satte sig ned og planlagde det første forløb sammen – et forløb som Jane efterfølgende gennemførte. Hun værdsætter kollegaens hjælp og oplevede det som positivt at eleverne var aktive og ser hands-on som centralt i natur/teknik.

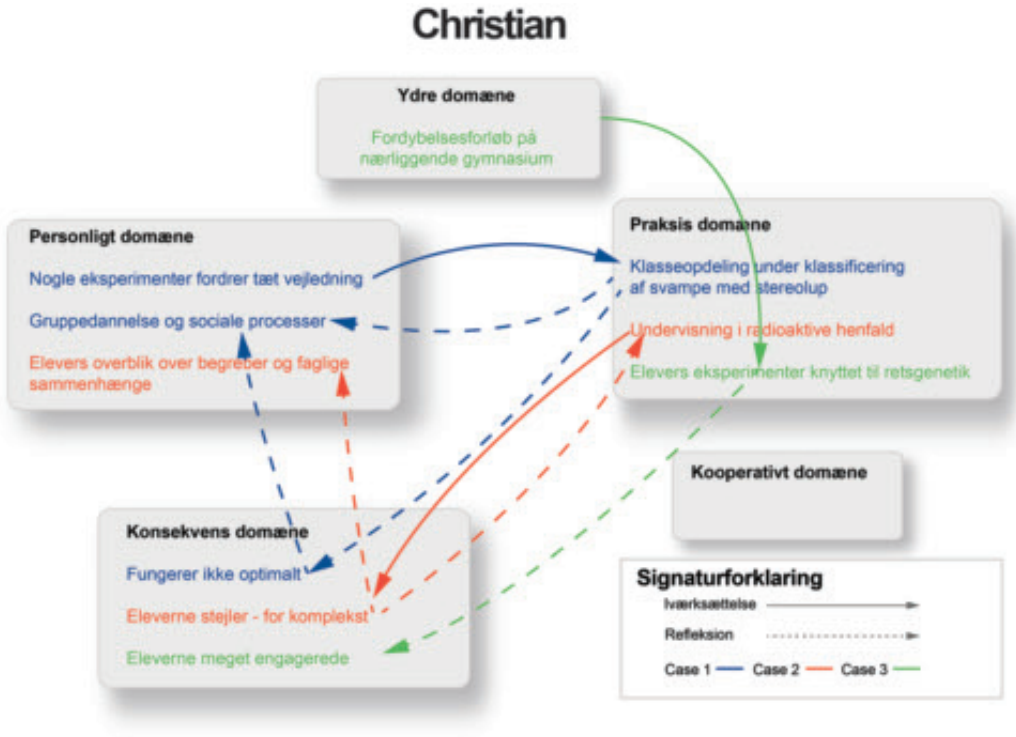
Det kooperative domæne ser ud til at være nøglen i Janes meningskonstruktion. De kollegiale samspil støtter hende i at eksperimentere i praksisdomænet. I fortolkningen af erfaringerne (det personlige domæne) virker det som om hun har udviklet et vist niveau af PCK ift. undervisning i geografi fra læreruddannelsen, fx i begrundelsen for aktuel geografi, og i den kontekstspecifikke erfaringsfortolkning. Derimod oplever hun stor usikkerhed og et manglende repertoire i natur/teknik og går pragmatisk praktisistisk i gang ved at kopiere noget der virker for en kollega. Hun refererer ikke til hvad eleverne skal lære, ligesom hun gør i overvejelserne om geografi. Elevernes hands-on-aktiviteter, som afspejlet i kollegaens forløb, bliver reference i evaluerin-gen af om undervisningen er en succes, og afgørende for hendes planlægning af nye forløb. Jane bekræfter sin forskellige tilgang til de to fag. Hands-on er ikke en nød-vendighed for at hun oplever en undervisningsgang i geografi som en succes. Hun henviser meget til begrebsspil og struktureret gruppearbejde (kooperativ læring). Når hun refererer til hvordan hun anvender "det hun har med fra læreruddannelsen", er det også geografi og bacheloropgaven. Brugen af struktureret gruppearbejde er bl.a. baseret på hendes undersøgelse i bacheloropgaven af 9.-klasses-elevers manglende engagement i diskussion/gruppearbejde.

Det der er repræsenteret i figur 2, er de episoder Jane spontant fremhæver. I forbin-delse med at hun bliver spurgt mere ind også til mindre positive oplevelser, nævner hun at en fysikkollega i indeværende skoleår er hjælpelærer i *hendes* undervisning. Hun oplever dette som ubehageligt, også efter ½ år, selvom hun godt kan lide ham personligt, og han har understreget at han ikke kontrollerer det faglige. Som begrun-delse henviser hun til sin manglende tiltro til sin egen naturfaglige kompetence. Jane slutter af med at nævne et fagligt geografikursus på et naturcenter som har været inspirerende, men ikke er blevet omsat til undervisning da hun ikke har de muligheder i hverdagen der var på naturcenteret. Hun fremhæver desuden at hun glæder sig til nogle kommende inspirationsdage hvor kommunens geografilærere skal mødes og erfaringsudveksle.

Christian

De situationer som Christian fremhæver, er repræsenteret i figur 3. Den første case (blå) er fra undervisningen på mellemtrinnet hvor han på forhånd havde overvejet hvordan han kunne få tid til at hjælpe eleverne med at undersøge og klassificere svampe med brug af stereolup. Han valgte at lade halvdelen af klassen arbejde med en skriftlig opgave imens han hjalp den anden halvdel, og begrunder dette med at arbejdet med stereolup er komplekst. Opdelingen fungerede dog ikke optimalt, og han reflekterer over hvordan han kan organisere klassen bedre i fremtiden, og over elevernes læringsmæssige udfordringer. Den anden case (rød i figur 3) starter i praksisdomænet da det ikke var noget han bevidst havde planlagt at afprøve. Under

undervisning i fysik, i radioaktive henfald, går det op for ham at eleverne slet ikke fanger pointerne – det er for komplekst, han har alt for meget med, de stejler totalt, som han formulerer det. Han overvejer hvordan han kan kvalificere det til næste gang og støtte eleverne til at få et overblik.



Figur 3. *Meaning-making map: Christian.*

Christian fremhæver eksplicit at han synes han lærer mest ved det der ikke fungerer så godt. Hans typiske måde at lære på er at afprøve noget og så forbedre det der ikke fungerer, fremadrettet. Adspurgt om oplevelser af noget der har fungeret godt, nævner han den tredje case (grøn i figur 3): at han og eleverne har deltaget i et fordybelsesforløb på et nærliggende gymnasium. Laboratoriefaciliteterne har givet eleverne mulighed for at eksperimentere med kompleks retsgenetik, og det har motiveret dem meget.

Christian har ikke ligesom Jane henvist til kollegerne i sine eksempler. Adspurgt fremhæver han dog i positive vendinger kollegasamarbejdet blandt naturfagslærerne. Han nævner at de på teammøder deler idéer og erfaringer, og kommer med eksempler både hvor han selv har fremlagt noget, og hvor han har fået ny inspiration fra kollegerne. Han henviser endvidere til et kursus uden for skolen. Det har handlet om rent praktisk at udvinde jern. Han har ikke brugt det endnu, men vil afprøve det næste år med sin fjerdeklasse som han mener vil kunne få mere ud af det i femte.

Christian fremhæver i øvrigt oplevelsen af *ikke* at være forberedt til fortsat læring

i praksis da læreruddannelsen ifølge ham ikke er præget af en undersøgende kultur. Han ser et stort potentiale i at man som lærer udvikler sin praksis iterativt, gennem afprøvning, undersøgelse af elevernes læring og revidering, og han nævner ligesom Jane de undersøgelser (video) de har lavet i forbindelse med deres bacheloropgave. Han mener dog det har været svært at omsætte resultaterne til praksis da hans undersøgelse inddrog Lego Robolab, en tidskrævende type aktiviteter, og han er kommet på en skole med meget vægt på "det faglige".

Cases fra de to lærere bekræfter læringsepisodernes personlige og situerede karakter: betydningen af det omgivende forandringsmiljø. Repræsentation som meaningmaking maps synliggør kompleksiteten og de individuelle forskelle, men også mønstre og ligheder træder frem. Begge lærere lægger vægt på elevernes "reaktioner" når de fortolker en oplevelse som positiv, men hvad det er for reaktioner, varierer fra aktive elever med hands-on til at grundlaget er mere specifikke analyser af elevernes begrebsudvikling. For dem begge gælder at deres fortolkning af erfaringerne i det personlige domæne bliver medieret via en bevidst afprøvning eller via det kooperative eller ydre domæne. Det fælles ville være endnu tydeligere hvis Christians overvejelser om at dele egne erfaringer med kollegerne og inspireres af deres erfaringer (loop mellem praksisdomænet og det kooperative domæne) var tegnet ind, men jeg valgte at nøjes med de spontane cases.

For at sætte de erfaringer som Jane og Christian fremhæver, i perspektiv vil jeg nu inddrage nogle udvalgte resultater fra anden runde af kohorteundersøgelsen: Hvilke erfaringer fremhæver lærerne fra kohorten, hvordan fortolker de dem, og hvordan oplever de at indgå i samarbejde om naturfagsundervisning?

Resultater: kohorten

Både Jane og Christian kom til at undervise bredt i naturfag. Kohorteundersøgelsen viser at der både på første og på andet år efter afsluttet uddannelse er cirka 30 % af lærerne som *ikke* gør det. På andet år er der 23 % der har job som lærer, men ikke har naturfag på skemaet, mens 6 % slet ikke arbejder som lærer. Begrundelserne fra dem uden naturfag på skemaet varierer. De fleste angiver skematekniske grunde, men der er også flere eksempler hvor begrundelsen er manglende faglig sikkerhed:

> "Jeg ville desuden heller ikke føle mig tryg ved at undervise i biologi da jeg føler jeg har glemt alt siden jeg afsluttede det på 2. år på seminariet. Jeg er overhovedet ikke naturvidenskabelig i min tankegang eller interesse, så min viden forsvandt hurtigt."

Fortolkning af oplevelser fra naturfagsundervisning

Det blev centralt hvordan Jane og Christian fortolkede deres erfaringer fra praksis; de fremhæver på forskellig måde elevernes "reaktioner". Lærerne fra kohorten er også meget centreret om eleverne når de begrunder hvad der er positive og mindre positive oplevelser fra deres undervisning i naturfag. Når det gælder positive oplevelser (tabel 1), er begrundelser med reference til at noget har været *vedkommende for eleverne*, mest udbredte (36 %):

> "Sammenhængen mellem teori og praksis. Det blev vedkommende og autentisk og kunne relateres til deres egen hverdag."
> "Jeg synes det var vellykket fordi udgangspunktet tages i eleverne og deres opfattelse af et hverdagsfænomen. Det vækker deres interesse og gør stoffet vedkommende."

Elevernes læring	Vedkommende for eleverne	Elevernes aktivitet (hands-on)	Selv som lærer godt hjemme i stoffet
32 %	36 %	28 %	4 %

Tabel 1. *Begrundelser for positive erfaringer fra undervisning i naturfag. De lærere fra kohorten der underviser i naturfag, regnes som 100 %.*

28 % af lærerne refererer til elevernes aktivitet:

> "Eleverne var aktive og syntes det var fedt at få lov til at lave forskellige forsøg."

mens 32 % bliver specifikke om hvad det er eleverne lærer af aktiviteterne:

> "Dissekering af svineøjet var en stor øjenåbner for mange, og de fik en bedre forståelse af hvordan øjet er bygget op."

Jeg vil nedenfor diskutere nogle udfordringer relateret til disse forskellige måder at fortolke erfaringer på – nogle udfordringer der også træder frem ved at analysere lærernes begrundelser for noget der ikke har fungeret så godt (tabel 2).

Mislykket forsøg	Elevernes læring: minus sammenhæng, over deres niveau m.m.	Manglende hands-on	Problemer med uro m.m.	Mangler selv fag-faglighed	Mangler fagdidaktisk viden
9 %	32 %	27 %	9 %	18 %	4 %

Tabel 2. *Begrundelser for erfaringer med mindre vellykket undervisning i naturfag. De lærere fra kohorten der underviser i naturfag, regnes som 100 %.*

De nye lærere gør sig forventeligt nogle erfaringer ved at følge lærebogens forslag. 9 % henviser til forsøg der ikke lykkes:

> "De mikroskoper vi har, kunne slet ikke forstørre nok, og så gik det hele i vasken."

Argumenter om elevernes manglende læring udgør ca. 1/3, men næsten lige så mange har igen særligt fokus på om eleverne er aktive. Derudover er der eksempler på oplevelsen af fag-faglige begrænsninger hos 18 % (og det er altså af de lærere der har fået undervisning i naturfag på skemaet):

> "Et fagområde som jeg selv finder meget vanskeligt. Derfor var det svært at fange eleverne."
> "Kunne ikke finde svar på mine egne spørgsmål til emnet."

Christian er meget tilfreds med at undervise i naturfag, og Jane relativt tilfreds – de vil begge gerne fortsætte med det. 57 % af lærerne fra kohorten svarer at de er tilfredse eller meget tilfredse, 15 % er i den midterste Likert-kategori, og 28 % er utilfredse eller meget utilfredse. Mens de tilfredse understreger at *eleverne* er glade for naturfag, fremhæver flere af dem der er utilfredse, faglig usikkerhed:

> "Jeg føler mig meget usikker i faget, synes ikke det falder mig naturligt at få idéer og undervise som jeg synes der skal undervises."

Samarbejde med kolleger

Janes eksempel viser at samarbejde, herunder med en mentor, får stor betydning, og tidligere danske undersøgelser har også vist at skolemiljøet er afgørende for natur/tekniklæreres self-efficacy og mod til at agere innovativt (Ellebæk & Evans, 2005; self-efficacy skal forstås som tiltro til egen kompetence: Bandura, 1982).

Hvordan ser samarbejdet om naturfag ud for lærerne fra kohorten? Lærernes svar

når de bliver spurgt til samarbejde, kan sorteres i tre næsten lige store grupper. 28 % siger at der overhovedet ikke er samarbejde om naturfag på skolen:

> "Desværre er der ikke samarbejde inden for de naturvidenskabelige fag. Her passer man lidt sig selv."
> "Ikke det fjerneste. Hver passer sig selv og forsvinder hurtigst muligt fra skolen."

Modsat dette oplever 34 % højt niveau af samarbejde:

> "I faget fysik/kemi er der udbredt samarbejde mellem lærerne om undervisningen."
> "Vi står over for at alle vi naturfagslærere skal sætte os sammen og prøve at lave en rød tråd i undervisningen."

De sidste 38 % er en mellemgruppe med noget, men ikke meget, kollegialt samarbejde, herunder eksempler der ikke kan karakteriseres som egentligt samarbejde:

> "Ikke meget, men jeg har f.eks. bestilt ekstra hæfter og plakat om nedbrydning og affald for at kunne give det til et andet team."

De skoler hvor samarbejde prioriteres, er også længst fremme med introprogrammer og mentorordninger. Her er ligeledes stor variation, fra lærere der svarer at de overhovedet ikke har været del af en formel intro, til dem der har oplevet gode og velplanlagte forløb.

Diskussion

Hvilke udfordringer og muligheder for fortsat læring i praksis kan indkredses? Først og fremmest kan det ses som en *udfordring* at næsten en tredjedel af en kohorte med naturfaglige linjefag på andet år stadig ikke har undervisning i fagene, og at det for i hvert fald nogle af dem handler om faglig usikkerhed. Det indikerer, set sammen med refleksioner fra en del af dem der har undervisning, et behov for konkret støtte. Det må dog også understreges at en stor gruppe er glade for at undervise i fagene, føler sig fagligt kompetente, oplever engagerede elever og kommer med konkrete eksempler på rammesætning af elevernes læring. De to lærere der er fulgt nærmere, hører til dem der er kommet i gang med at undervise i naturfag og er relativt tilfredse med dette. Dog har især Jane mødt nogle udfordringer. Jeg vil med afsæt i dette diskutere muligheder og udfordringer nærmere under to overskrifter: at lære ved at afprøve i praksis og at lære i kollegialt samspil.

At lære ved at afprøve i praksis

Eksperimenter i praksis – at afprøve noget i undervisningen og efterfølgende reflektere over det – er den hyppigst nævnte læringsproces fremhævet af erfarne lærere (Bakkenes et al., 2010). Resultaterne her viser at også de to nye naturfagslærere oplever at udvikle sig professionelt via afprøvning og refleksion over hændelser i praksis. Samspillet mellem praksisdomænet og det personlige domæne, med støtte fra refleksion via konsekvensdomænet, går igen.

Eraut (2004) fremhæver som refereret ovenfor fire hovedaktiviteter der typisk igangsætter læring. Ud over de to typer af kollegiale aktiviteter er det "at tackle udfordrende opgaver" og "at arbejde med klienter". Hvis det lykkes at tackle udfordrende opgaver, kan det ifølge Eraut føre til oplevelse af stigende motivation og self-efficacy. Det kan perspektivere Janes eksempel hvor hun udfordrer sig selv til at inddrage aktuelle episoder i sin undervisning og oplever at det lykkes – den risiko hun tog, blev belønnet. Jane støttes tilsyneladende i sin tiltro til egen kompetence af succeserne der sammen med mentorens opfordring bekræfter hende i fortsat at eksperimentere professionelt. Christian, der som udgangspunkt har en større tiltro til egen kompetence, fremhæver meget bevidste eksperimenter og specifikt det at lære af de ting der går galt, men også for ham er det arbejdet konkret med eleverne (Erauts "klienter") og de udfordrende opgaver i klasserummet som fremhæves. Læringspotentialet, *mulighederne*, via refleksion over afprøvninger i praksis er altså tilsyneladende stort, men et støttende miljø ser ud til at være afgørende så de nye læreres usikkerhed ift. undervisning i naturfag ikke bliver spærrende for deres fortsatte innovative tilgang.

I de to læreres fortolkning af deres erfaringer er der i konsekvensdomænet flere eksempler på konkret feedback fra elevernes "reaktioner". Christian nævner specifikt elevernes begrebsforståelse og læring, og både Jane og Christian nævner elevernes motivation og engagement. Lærerne i kohorten inddrager også i udpræget grad elevernes "reaktion" i deres fortolkning af erfaringerne. For en del af dem er det elevernes læring, som i eksemplet med dissekering af svineøjet, men mange er specifikt fokuseret på at eleverne er aktive og har hands-on.

Dette giver anledning til nogle overvejelser. Hvor vigtigt det end er at eleverne kommer op fra stolene og er tilfredse og engagerede, er det ikke givet at de lærer naturfaglige begreber og sammenhænge alene gennem aktiviteter. Forskningen viser at lærerens fokus på hvordan eleverne udvikler begrebsforståelse ved at manipulere *både* med idéer og med udstyr og artefakter (hands-on + minds-on) er helt central (Abell & McDonald, 2006; Lunetta et al., 2007). Fokus på aktiviteter som et mål i sig selv, mere end hvad eleverne lærer gennem aktiviteterne, ses fx i Janes refleksioner over starten med natur/teknik. Hun kommer i gang, inspireret af en kollega, som en overlevelsesstrategi, men uden refleksion over hvordan eleverne kan engageres i manipulering med naturfaglige idéer. En vigtig overvejelse i relation til denne *ud-*

fordring er hvordan naturfagslærerne kan få værktøjer med fra læreruddannelsen til løbende at udvikle og fastholde et fokus på elevernes begrebsudvikling, og hvordan professionelle udviklingsaktiviteter kan designes så de understøtter naturfagslærerne ude i praksis i dette. Christians fremhævelse af en manglende undersøgende kultur i læreruddannelsen maner her til eftertanke.

At lære i kollegialt samspil

Janes cases har alle fokus på kollegiale interaktioner. Hun er ligesom Christian på en skole hvor der er et vist niveau af samarbejde mellem naturfagslærerne. En første *udfordring* der kan identificeres ved inddragelse af resultaterne fra kohorten, er at dette ikke er et generelt billede. Der er en del skoler med tæt samarbejde, herunder støtte til nye lærere, men der er næsten lige så mange skoler hvor de nye naturfagslærere omtaler begge dele som ikkeeksisterende. Muligheden for læring gennem kollegial interaktion understøttes altså ikke på alle skoler:

> "Workplaces differ a lot in how they support learning." (Tynjälä, 2008, s. 140)

Mht. læring gennem kollegial interaktion nævner Eraut (2004) to typer: deltagelse i gruppeaktiviteter og teamarbejde styret af et fælles mål og at arbejde side om side med kolleger, observere og lytte og blive opmærksom på kollegernes viden og kompetence, herunder at få et indblik i deres tavse viden. Janes spontane eksempler kan bedst karakteriseres som uformelt at få idéer fra kollegerne, og det samme gælder de eksempler Christian fremhæver. Selvom der er fungerende naturfagsteam på de to skoler, virker det i Janes og Christians referencer ikke som egentlige professionelle læringsfællesskaber (McLaughlin & Talbert, 2006) med undersøgelser og diskussioner styret af fælles mål. Hvorvidt der er et uudnyttet potentiale for mere formelle kooperative læringsaktiviteter på de pågældende skoler, og på kohortelærernes skoler, går ud over datagrundlaget, men det kunne man have en hypotese om baseret på anbefaling om læreres kollektive deltagelse i undersøgelse af elevernes læreprocesser som der refereres til i baggrund ovenfor. Hvorvidt de nye lærerne så er interesseret i mere tætte relationer der betyder at døren til deres klasserum i højere grad skal åbnes for kollegerne, er et spørgsmål. Som ny lærer har Jane fået meget ud af at være med i kollegers undervisning, men oplevelsen af ubehag ved at have en erfaren fysikkollega til at overvære sin undervisning er også tydelig. Dette har ikke styrket hendes self-efficacy – tværtimod oplever hun at det har gjort hende mere usikker.

At dele eksperimenter i og kritisk refleksion over egen praksis med kolleger kan være meget følsomt, men støtte til skolebaseret udvikling må ses som en central tilgang til udvikling af naturfagsundervisning. Eraut (2004) peger på at læringspotentialet i praksis sjældent udnyttes fuldt ud. Læring blomstrer i nogle arbejdspladskontekster,

mens den stagnerer eller stopper i andre – et samarbejdsklima der er fremmende for læring, er nødt til at blive skabt, vedligeholdt og genskabt med jævne mellemrum.

Konklusion og perspektivering

Baseret på to naturfagslæreres konstruktion af forståelse og fortolkning af erfaring fra en række situationer fra deres første år i praksis, sat i perspektiv af refleksioner fra en kohorte af naturfagslærere, er der identificeret en række udfordringer og muligheder for naturfagslærernes fortsatte læring i praksis.

De eksempler de to lærere fremhæver, kan kategoriseres under to overskrifter: at lære ved at afprøve i praksis og at lære i kollegialt samspil.

Mulighederne ved læring gennem afprøvning i og refleksion over praksis illustreres af eksempler fra dem begge. Bl.a. støttes Jane i sin tiltro til egen kompetence og fortsat innovativ tilgang til undervisning af en succesoplevelse hvor hun udfordrer sig selv, mens Christian fremhæver mere bevidste eksperimenter og specifikt at lære af de ting der går galt. Herudover ser der ud til at være muligheder for læring gennem forskellige typer af kollegiale samspil, muligvis med et uudnyttet potentiale for mere strukturerede kooperative aktiviteter på skolerne. Udfordringer der er identificeret, er ud over dette at det kan være helt centralt hvad det er lærerne fokuserer på når de fortolker deres erfaringer fra afprøvninger i egen praksis: om det bliver elevernes naturfaglige begrebsudvikling, eller om succeskriteriet begrænser sig til glade og aktive elever. Derudover er der udfordringer forbundet med at en del af de nye naturfagslærere med naturfaglige linjefag føler sig usikre fagligt, med relativt lav self-efficacy, som set i tidligere undersøgelser (fx Ellebæk & Evans, 2005). Janes eksempel indikerer at dette kan betyde ekstra behov for kollegial støtte, her særligt støtte til at udfordre sig selv og afprøve nye tilgange i undervisningen. Udfordringen for læring i kollegialt samspil er først og fremmest de store forskelle fra skoler hvor hver naturfagslærer passer sit, til skoler med en højere grad af samarbejde om naturfagsundervisningen.

Brugen af en tilpasset "meaning-making model" til at analysere og repræsentere de to læreres erfaringer har været med til at tydeliggøre en række individuelle og komplekse sammenhænge, men også hvordan nogle mønstre går igen. Fremadrettet kan det specifikke fokus på lærernes konstruktion af forståelse og fortolkning af erfaringer forhåbentlig inspirere både når det gælder hvordan man kan understøtte læreres fortsatte læring i praksis, og hvordan man kan undersøge og repræsentere denne.

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English Abstract

We analyse two science teachers' construction of understanding and interpretation of experiences from their first practice and represent them via a meaning-making model. Based on this and on data from a cohort study a range of possibilities and challenges for novice science teachers' learning in practice are identified. The possibilities are exemplified and discussed under two headings: learning through experiments in practice and learning through peer interactions. Challenges are identified regarding what the teachers focus on in their interpretation of experiences: is it students' learning or satisfied and active students? The primary challenge regarding learning through peer interactions is the big differences in the level of cooperation among science teachers at various schools.

Appendix 5

Codebooks

- Codebook used in analysis in the study presented in paper III. “Pre-service teachers’ meaning-making when collaboratively analyzing video from school practice to be used in the bachelor project at the college”.
- Codebook used in analysis in the study presented in paper IV “Naturfagslæreres konstruktion af forståelse og fortolkning af erfaring”

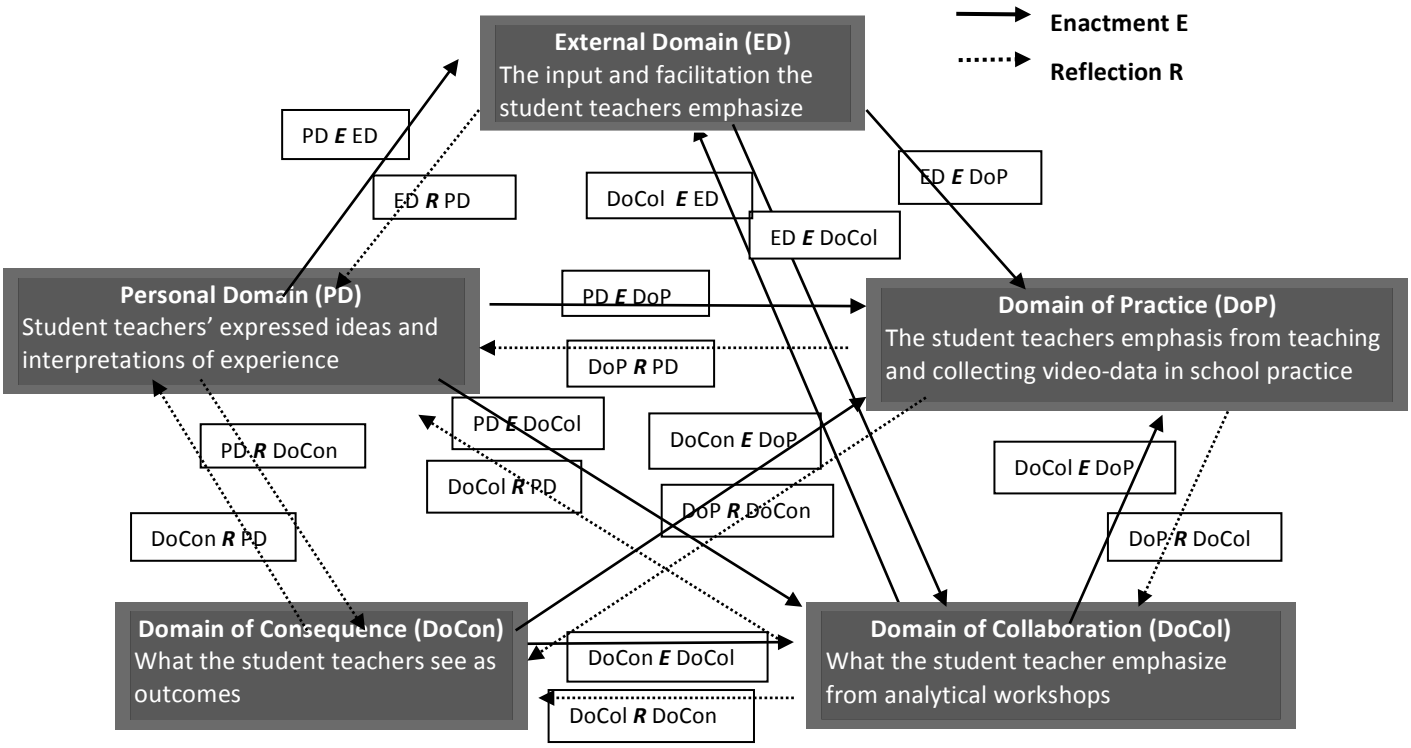
Codebooks used for the research presented in paper I and II are published in the papers (appendix 1 and 2)

Codebook: *Pre-service teachers' meaning-making when collaboratively analyzing video from school practice to be used in bachelor projects at the college*

Step 1: Codes referring to the five domains in the meaning-making model. The student teachers' utterances might in this step of analysis have reference to more than one domain.

Code	Description
External Domain (ED)	The student teacher refers to **input** of reading material, research results tools etc. and to **facilitation** in the analytical workshops.
Domain of Practice (DoP)	The student teacher refers to purposefully **trying something out** in school practice: questions and actions related to the video-based inquiry and/or the concrete classroom teaching.
Domain of Collaboration (DoCol)	The student teacher refers to **interactions and dialogues** from the analytical workshops related to analysis and discussion of peers' video or to their own video.
Domain of Consequence (DoCon)	The student teacher refers to what he/she sees as **perceived outcomes**: positive outcomes and/or negative experiences and frustrations.
Personal Domain (PD)	The student teacher refers to **ideas** about teaching, learning and school students as learners, to **interpretations of experience** from school practice or other teaching experience and/or to themselves or teachers in general as learners.

Meaning-making model with all domains and arrows (step 2 coding):



Step 2: Codes referring to how change in one domain is connected to other domains, with reflection and enactment as mediating factors. Coding is used on utterances where *more* than one code is used in step 1.

Code	Description	Quote
PD ***E*** ED	The student teacher refers to personal request and search for new 'information' from ED	No examples
ED ***R*** PD	The student teacher reflects on personal use of input and facilitation from ED	No examples
ED ***E*** DoP	The student teacher refers to start of "experimentation in practice" based on input from ED	No examples
PD ***E*** DoP	The student teacher refers to the ideas behind teaching and inquiries in school practice	*I planned a debate* (..) it *was about using the scientific concepts* (Louise first interview)
DoP ***R*** PD	The student teacher reflects on personal experiences from teaching in school- experiences that verified or potentially changed ideas about teaching and learning	*I wonder about the school students dialogue in the group* (.) *is it only practice sharing* (Christian first interview)
ED ***E*** DoCol	The student teacher refers to input of tools or facilitation in relation to the workshops	*The hardest part was to analyze the data* (..) *I used* this(..) *the tools and the models* (Christian second interview)
DoCol ***E*** ED	Reference to collaborative request and search for new "information" from ED	No examples
DoCol ***E*** DoP	The student teacher refers to how discussions in workshops lead to/induced/started experimentation in practice (or might do so looking forward)	No examples
DoP ***R*** DoCol	The student teacher reflects on how "experiments" from own classroom were used in the workshops	*To present and* (...) *reflect collaboratively is* (..) *a learning process* (Marie second interview)
DoCon ***E*** DoCol	The student teacher refers to outcomes and how this entails (or might entail) new/changed/more/less peer- interactions	No examples
DoCol ***R*** DoCon	The student teacher reflects on something which happened during workshops as being an outcome	*I think it was good it was a structured dialogue* (Marie second interview)
DoCon ***E*** DoP	The student teacher refers to outcomes and how these entail (or might entail) new/changed/ more/less "experimentation in practice"	No examples
DoP ***R*** DoCon	The student teacher reflects on outcomes from experiences when teaching in school practice (positive or negative)	*I do not master the situation* (..) *to see what I did myself it was harder than I imagined* (Jane first interview)
DoCon ***R*** PD	The student teacher refers to outcomes and includes reflection on ideas about teaching and learning	*I think it was really hard to watch my own mistakes* (..) *when watching the video it is as if they did not have a discussion with each other but with me* (Louise second interview)
PD ***R*** DoCon	The student teacher uses ideas about teaching and learning in reflection on what the outcomes are	*I gained from using video bridging theory and practice (..)but also difficult (..)you have a tendency to look for things to use related to the theories you know* (Marie, second interview)
DoCon ***R*** PD	The student teacher reflects on a change in ideas about teaching and learning based on discussions in workshops	No examples
PD ***E*** DoCol	The student teacher refers to ideas about teaching and learning and uses this as a argument for new/changed /more/less peer-interactions	No examples

Step 3: Categorizing the content of utterances belonging to each domain – derived from open coding

	Code	Quotes
Personal Domain	**Planning teaching** for school practice	Cooperative learning (..) open questions in relation to this kind of issue (Marie FI) Planned a debate (..) it was about using the scientific concepts (Louise FI) I wanted the student to understand the big ideas (Jane FI)
	Evaluating teaching from school practice and relating this to students learning and/or their affective reactions	The students were frustrated because the problem had no clear solution (..) this was hard (..) evaluation (..) it made an impressions (..) they were forced to take a stand (Marie FI) I wonder about the students dialogue in this group (..) is it only practice sharing (..) do they develop ideas together (Christian FI) They were really bad at working in groups (Jane FI) I did not think about it in advance (..) it really made a difference if someone laughed (..) it might have been hard for them to stand in front of the class (Louise SI) Student might need narrative approaches (Marie SI) There has to be a classroom environment where the students are exploring (Jane SI)
	Managing classroom discourse	When are the student talking and when is it only me talking (Jane FI) Many times you should give them a second more before interrupting (Louise SI)
	Learning as a teacher Meta-reflection	You want to see something related to theory and you cannot always (..) I wonder if you sometimes add the theory for the theories own sake (Marie SI) The context where you end out working might be the most important (Christian SI) The problem I started with was not the one I ended out with (..) I changed based on video-analysis (Jane SI)
Domain of consequence: Outcomes as ST in relation to the task of making a bachelor project	**T-theory versus t-theory.** Positive outcomes related to taking practice as a starting point before including theory	To act in practice and then read theory with new eyes (..) has been really helpful, but also hard because you want to see something related to theory and you cannot always (Marie SI) This was the first time we studied and analyzed practice and then found the useful theory afterwards (..) it is opposite to the other tasks (Christian SI) I have seen the connection of theory and practice more than before(..) former tasks, at least in pedagogy, have been very theoretical (..)the very philosophical stuff is hard to see in a situation in practice(..) I have developed my project based on video-analysis (..)it was good to have a concrete starting point (..) to realize which theory I could use (Jane SI) It was a jump forward when I read the theory after school practice (..) suddenly I saw how to focus (..) every time I read something I thought (..)what about practice (Louise, SI)
	Structured dialogue. Describe before analyze and interpret	I think it was good that it was a structured dialogue and still a free and open dialogue (..) the big difference between describing, analyzing and interpreting (Marie SI) Focus with a fresh eye on the professional issue in a structured dialogue (Christian, SI) The professional issues, the structured discussions, kept the group together (Jane SI) The new eyes (..) and the professional structured perspective (Louise, SI)
	Collabora-tion Gaining from peer-reflections	My reflections developed by watching the others'(..)observe your own with new eyes (..)to present and (..) reflect collaboratively is (..) a learning process (Marie SI) I used this [contribution from the group] in how I could see (Christian SI) Collaborate (..) to find words for what you have seen (Jane SI) Much I did not see myself (..) perspectives I had a hard time finding myself (..)they managed to ignore me when I tried to explain myself out of a situation (Louise SI)
	Tool for video-analysis.	How to approach and analyze (..) this was the definite leap forward (Marie SI) The hardest part was to analyze the data (..) I used this (..)the tools and models (Christian, SI)

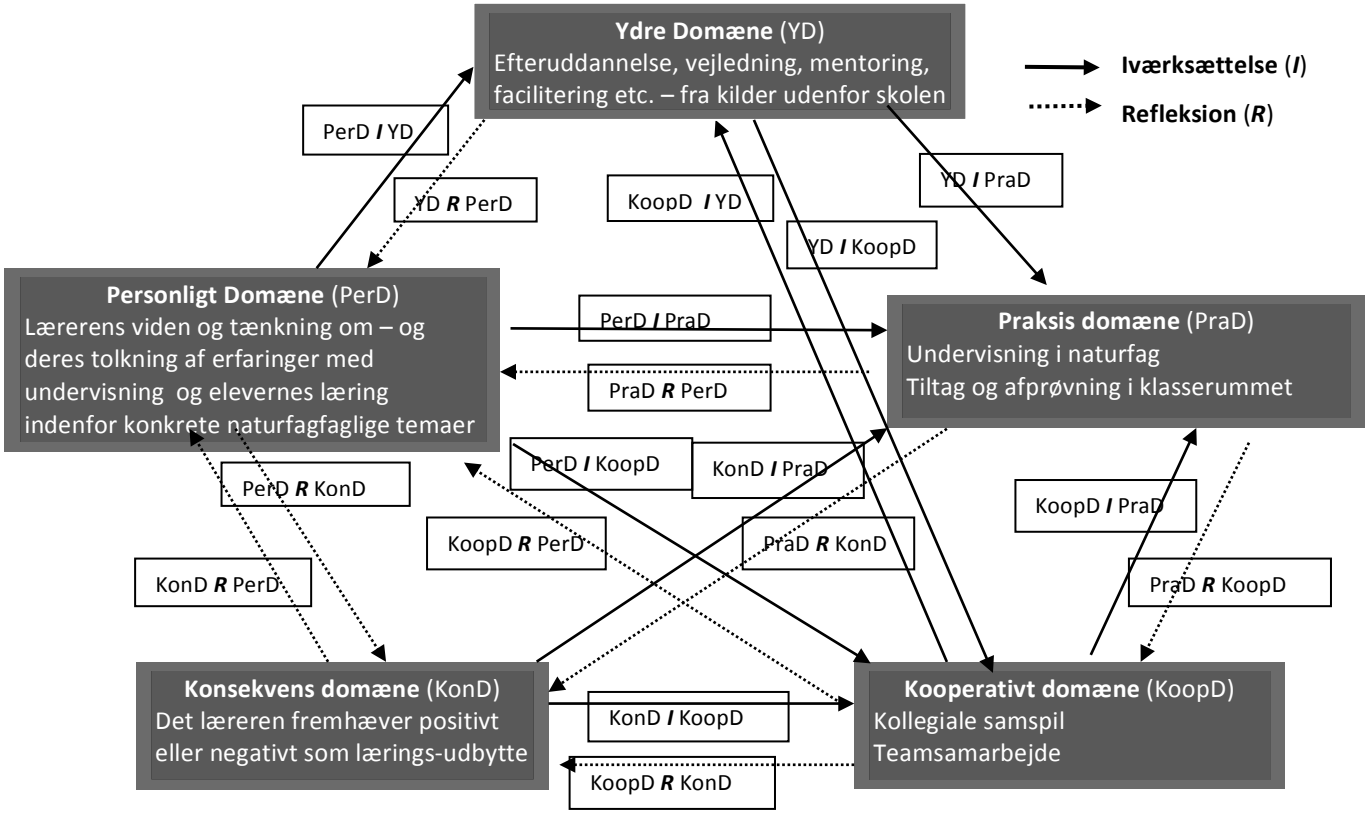
	Mastering making the bachelor project.	Worries: I realize it is very ambitious (..) when I knew it was filmed, I hoped they[the school students] would say something more and better, and I was extremely frustrated just after (Marie FI) I do not know how to focus and what I want to use (Jane FI) Contentment: I knew already when returning from the summer holiday how to arrange it and all agreements with teachers were made (Christian, FI) The bachelor process has been good intense and different (Jane, SI)
	Expected from the college	There are huge differences (..) what the professors want us to do in our project (Jane, SI) I think it has been hard to find out what was actually expected in this task (Louise, SI)
Domain of consequence: Classroom teaching	**Mastering** classroom tea-ching	Worries: They wanted me to stand and talk but when I did so they were noisy(..)I do not master the situation (..)to see what I did myself, it was harder than I imagined (Jane, FI) I think it was really hard to watch my own mistakes (Louise, SI) Contentment: It worked well for me to try to push them, make them do it themselves (Christian FI)
	Continuing learning as a teacher	Reality is unique, to keep this in focus (..) yourself being in a learning process (Marie SI) My results have shown that the kind of teaching you use often(..) you can do something else (..) I am not sure how this will effect my practice I might be more reflective (Christian SI)
Domain of collaboration	**Analytical workshops**	To present video from your teaching and reflect collaboratively (..) was a learning process (Marie SI) You cooperate about it (..) and get words for what you have seen (..) if I had analysed the excerpts myself I would not have focused so much on the students' learning more on myself as a teacher (Jane SI) They managed to ignore me when I tried to explain myself out of a situation (Louise SI) I used this [contribution from the group] in how I could see (Christian SI)
Domain of practice	**Inquiry as student teacher (ST)**	The issue I am examining is how to develop students intercultural competencies (Marie FI) I want to see if First Lego League can be a motivating factor (..) it is not necessarily motivation to learn science (Christian FI) I want to examine if it is possible at all (..) can the students take their own stand (Jane FI) I want to look at what can help the school students to be better at arguing and discussing issues (Louise, FI)
	Classroom teaching (CT)	The student were working in groups (..) the aim was that they gained an understanding of being young and from Sudan (Marie FI) The students were building lego robots (Christian FI) I tried to make questions to start a discussions but they did not discuss (Jane FI) We made a role-play like a big debate where they had a week to prepare (Louise FI)
External domain	**Input**	I used the tools I got and the approach (Marie SI) I used this how I could analyse the video (..) I used the model we got to analyse (Christian SI)
	Facilitation	I think it was good that it was a structured dialogue and still a free and open dialogue (Marie SI) The professional issue in a structured dialogue (Christian, SI) The professional issues, the structured discussions, kept the group together (Jane SI)

Kodebog: Naturfagslæreres konstruktion af forståelse og fortolkning af erfaring

<u>Trin 1 kodning:</u> Koder med reference til de fem domæner i model til analyse af meningskonstruktion. Lærernes udtalelser kan på dette trin i analysen kodes som tilhørende mere end et domæne.

Kode	Beskrivelse
Ydre domæne (YD)	Læreren refererer til **input udefra**, f.eks. kurser, efteruddannelse, mentorprogrammer, proces-facilitering
Praksis domæne (PraD)	Læreren referer til den konkrete undervisning i naturfag: hvordan han/hun **iværksætter og afprøver noget i klasserummet**
Kooperativt domæne (KoopD)	Læreren refererer til **samspil med kollegaer**, både formelt rammesat i teamsamarbejde og mere uformelle samarbejder
Konsekvens domæne (KonD)	Læreren referer til hvad han/hun oplever som **læringsudbytte** – det kan være positivt læringsudbytte eller negative erfaringer og frustrationer
Personligt domæne (PerD)	Læreren referer til **hvad de ved, tænker og tror om undervisning og elevernes læring af naturfag**, og til deres fortolkning af konkrete erfaringer fra klasserummet. Lærerens syntese af faglig, fagdidaktisk og almendidaktisk viden med kendskab til den konkrete skole og klassekontekst.

<u>Meaning-making model med alle domæner og pile</u> (trin 2 kodning)<u>:</u>



Trin 2 kodning: Koder der refererer til hvordan forandring i et domæne hænger sammen med forandring i andre domæner med refleksion og iværksættelse som medierende processer, ad. figur ovenfor. Kodningen bruges på udtalelser hvor mere end en kode er brugt i trin 1. Eksempler/citater er fra analyse anvendt i artiklen: *"Naturfagslæreres konstruktion af forståelse og fortolkning af erfaring i den første praksis",* grå bokse er der hvor der ikke er eksempler i dette materiale.

Kode	Beskrivelse	Citater
PerD ***I*** YD	Læreren refererer til personlig efterspørgsel af – og/eller søgen efter nyt input fra ydre domæne	
YD ***R*** PerD	Læreren reflekterer over personlig brug af fx input og facilitering fra ydre domæne	
YD ***I*** PraD	Læreren refererer til afprøvning og iværksættelse i klasserummet baseret på input fra ydre domæne	*"..at fange eleverne på en ny måde, der har vi et samarbejde med (..) Gymnasium i et genetik forløb (..) eleverne laver-gelelektroforese .."*
PerD ***I*** PraD	Læreren refererer til begrundelser for - og den viden og de ideer der ligger bag ved iværksættelse af tiltag i praksis domænet	*"..jeg lavede noget opsplittet hvor nogle skulle kikke på svampe i stereolup (..)hvis de skal prøve reelt at klassificere svampe, kikke på hvordan det ser ud, beskrive og tegne (..) er der brug for læreren.."*
PraD ***R*** PerD	Læreren reflekterer over personlige erfaringer fra klasserummet – tiltag der har verificeret og/eller potentielt forandret viden – og ideer om undervisning i - og læring af naturfag	*"..lavet en masse forsøg med dem, og det har været godt (..) jeg kunne se hvordan man kunne gribe det an.."*
YD ***I*** KoopD	Læreren refererer til hvordan kollegiale samspil er blevet igangsat, faciliteret, fået input fra ydre domæne	*"..når man er ny lærer i (…) kommune, så har vi sådan en mentorordning, så jeg snakkede med ham om det.."*
KoopD ***I*** YD	Læreren referer til hvordan team af kolleger har efterspurgt input fra ydre domæne	
KoopD ***I*** PraD	Læreren refererer til hvordan kollegiale samspil og diskussioner har ført til iværksættelse af tiltag i praksis i klasserummet	*"..heldigvis gode kolleger (..).hun satte sig ned sammen med mig og lavede to lektioner (..)viste mig hvordan man skulle gøre"*
PraD ***R*** KoopD	Læreren reflekterer over erfaringer hvor tiltag fra eget klasserum er blevet delt med kolleger	*"..vi har fagteams, så fysiklærere mødes (..) noget fagligt ind over hver gang (..) kemisk analyse, hvor jeg har præsenteret (..)hvad det er jeg gør "*
KonD ***I*** KoopD	Læreren refererer til oplevet udbytte og hvordan det har ført eller kan føre til ny typer af, forandring i, mindre/mere kollegialt samarbejde	
KoopD ***R*** KonD	Læreren reflekterer over eget udbytte, positivt eller negativt, fra kollegiale samspil.	*"..mentorordning(..) vi har evalueret det (..) jeg tog det her op (..) støtte.."*
KonD ***I*** PraD	Læreren refererer til oplevet udbytte, noget de værdsætter, og hvordan dette kan føre til forandring i og/eller nye tiltag i klasserummet	*"..de var så engagerede (..) (..) jeg turde springe ud fra min årsplan (..)jeg prøver at tage noget mere aktuelt ind."*
PraD ***R*** KonD	Læreren reflekterer over udbytte fra iværksættelse af tiltag i klasserummet (positive eller negative)	*"kikke på svampe i stereolup (..) sideløbende spil (..) det lykkedes så ikke"* *"..de var så engagerede og synes bare det var spændende.."*
KonD ***R*** PerD	Læreren refererer til oplevet udbytte og bruger det i udvikling af/refleksion over viden og ideer om undervisning i naturfag	*"jeg sprang lidt ud på dybt vand (..) de synes bare det var spændende (..) det faglige med tsunamier(..) de ser det i fjernsynet hele tiden.."*
PerD ***R*** KonD	Læreren bruger viden og ideer om undervisning i – og læring af naturfag i refleksion som argument for, hvad der er det oplevede læringsudbytte	
KonD ***R*** PerD	Læreren reflekterer over en forandring i viden og ideer om undervisning i – og elevernes læring af naturfag baseret på kollegiale samspil	
PerD ***I*** KoopD	Læreren refererer til viden og ideer om undervisning i – og læring af naturfag og bruger dette i argumentation for mere/mindre/forandring i kollegiale samspil.	*"..jeg har natur/teknik i år som jeg ikke har haft før (..)pludselig gik det op for mig at jeg var på bar bund (..) fik fat på de andre natur/teknik kolleger"*

Appendix 6

List of Publications

Publications related to scientific work in the PhD-period 2009-2012.
The papers included in the thesis are marked with an asterisk (*)

Peer reviewed publications and conference presentations

* Nielsen B.L. (2012). Science teachers' meaning-making when involved in a school-based professional development project. *Journal of Science Teacher education,* DOI: 10.1007/s10972-012-9300-5

* Nielsen, B.L. (2012). Naturfagslæreres konstruktion af forståelse og fortolkning af erfaring i den første praksis. *MONA, 2012*(2), 37-53

* Nielsen, B. L. (2011). A cohort of novice Danish science teachers: Background in science and argumentation about science teaching. NorDiNa, 7(2), 202-218.

Nielsen, B. L. (2011). Patterns in the meaning-making of science teachers involved in a team-based PD project. Paper ESERA 2011, Lyon, France. Published in E-book- proceedings, part 13: In-service science teacher education, 145-151

Nielsen, B. L. (2011). Et skolebaseret udviklingsprojekt for naturfagslærere. Presentation, Nordic Research Symposium in Science Education, NFSUN, Linköping, Sweeden.

Andersen, H. M., & Nielsen, B. L. (2011). Video based analyses of motivation and interaction in science classrooms. *International Journal of Science Education*. DOI:10.1080/09500693.2011.627954

Nielsen, B. L., Caspersen, M. E., & Dahl, B. (2011). Hvad skal ph.d.-studerende på naturvidenskab vide om undervisning?. Dansk Universitetspaedagogisk Tidsskrift, (10), 18-24.

Pontoppidan, B., & Nielsen, B. L. (2011). First year pre-service science teachers' experiences of authentic instructional tasks in a PDS setting. Poster presentation, ESERA 2011, Lyon, France

Nielsen, B. L. (2010). Need for Danish science teachers' continual professional development after pre-service training. Paper presentation XIV IOSTE Symposium, Bled, Slovenia, Socio-cultural and Human Values in Science and Technology Education. Institute for Innovation and Development of University of Ljubljana. Published in the proceedings, p. 739-750

Nielsen, B. L. (2010). Enrolling science teachers in continual professional development. IND- KU skriftserie, 2010(18), 83-92.

Nielsen, B. L. (2009). Practice on the line - science teacher education in Denmark. Poster. ESERA 2009, Istanbul, Turkey

Ødegaard, M., Schoultz, J., Andersen, H.M., Mork, S., Hultman, G., Nielsen, B.L. (2009). Explora – Nordic project on talking science during explorative work in science classrooms, Symposium, ESERA 2009, Istanbul, Turkey

Nielsen, B. L., Rasmussen, K., & Brandt, H. (2009). Praktikvideo i læreruddannelsens naturfags- og matematikundervisning. *MONA 2009*(4), 50-67.

Non-Peer reviewed Publications

Nielsen, B. L. (2011). Det forskningsinformerede og udviklingsbaserede professionsbachelorprojekt. In Hedegaard, K. M., & Krogh-Jespersen, K. (Eds.), Professionsdidaktik: grundlag for undervisning i professionsrettet uddannelse, p. 229-247. Aarhus: KLIM.

Nielsen, B. L. (2011). Evaluering: Et naturfagligt perspektiv. In Petersen, B. V., & Thrane, M. (Eds.), Evaluering i skolen, p.41-64. Aarhus: KLIM.

Ødegaard, M., Andersen, H. M., Schoultz, J., Hultman, G., Nielsen, B. L., Löfgren, R., & Mork, S. (2011). Explora. Koding av elevers og læreres samtaler ved praktisk arbeid i skandinaviske klasserom. Kimen. Oslo: Naturfagscenteret.

Nielsen, B. L. (2010). Praktikvideo som praksisartefakt: brugt i teori-praksis kobling i bachelorprojekter i læreruddannelsen. In Beedholm, K., & Greve, C. (Eds.), Professionsdidaktik: et særligt anliggende for professionshøjskolerne? (p. 9-24). Aarhus: Via Systime.

Nielsen, B. L. (2010). Uddannelse til naturfagslærer: i krydsfeltet mellem teori og praksis. In Elmose, S., & Enggaard, K. (Eds.), Naturfagsdidaktik i anvendelse: fra forskning til praksis i 13 CAND projekter, p. 28-34. Aarhus: Via Systime