Educating Pre-service Science Teachers

Promoting PCK development through
the use of Lesson Study combined
with Content Representation

by

Martin Vogt Juhler

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"No one can think of everything simultaneously; we're just not constructed that way as human thinkers"

(Shulman, 2015, p. 23)

Dedicated to educators who are trying to make a difference

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Abstract

Recent research, both internationally and within Norway, has clearly expressed concerns about missing connections between subject-matter knowledge, pedagogical competence and real life practice in schools. This study looks at this problem within the domain of field practice in teacher education, specifically studying pre-service teachers' planning, teaching and reflection on a physics lesson. The aim was to change the field practice experience, so that it would contribute to the pre-service teachers' professional development in a better way than what is typically experienced, by specifically combining subject-matter knowledge, pedagogical competence and real life practice.

To approach this challenge, a two-year time lagged design experiment was conducted. During the first year (2012), a control group situation was studied. During this year, groups of pre-service teachers were followed as they worked together with their assigned mentor teachers during field practice. These groups prepared and conducted field practice as described in the National Curriculum Regulations. During the second year (2013), an intervention was studied. Similar to the first year, groups of pre-service teachers and their mentors were followed during field practice. However, during this second year, an intervention was introduced consisting of two components. The first was Lesson Study, which is a method for planning, carrying out and reflecting on a research lesson in detail with a learner- and content-centred focus. Lesson Study was used in combination with a second component, Content Representations, which is a systematic tool connecting overall teaching aims with pedagogical prompts. The above data collection was guided by and conducted as part of a larger project called Teachers as Students (TasS). The data was collected through video-recordings of two cycles of planning, conducting, and reflection on a field practice lesson.

This way of approaching the research question allowed for a comparison of differences between the two conditions. The difference was assessed using the construct Pedagogical Content Knowledge. This was chosen because someone with well-developed Pedagogical Content Knowledge has a rather deep understanding of the connections between subject-matter knowledge, pedagogical competence, and practice. Furthermore, many current researchers consider Pedagogical Content Knowledge as the developmental objective of the expert teacher.

The main research question that guided the investigation was formulated as follows:

> *“How does the use of Lesson Study combined with Content Representation affect pre-service physics teachers’ potential to start developing Pedagogical Content Knowledge during field practice in teacher education?”*

This main question was examined from different angles that resulted in four articles. The first two articles focus on describing the differences between the control situation and the intervention. The first article looks into the pre-service teachers’ planning of the first research lesson, while the second article looks into the pre-service teachers’ reflections after the first research lesson has been taught.

The first two articles present results that show that the pre-service teachers’ focus when planning and reflecting differs in specific ways when comparing the control situation with that of the intervention. Specifically, during the intervention the pre-service teachers had a much greater focus on the pupils and their learning, together with a much greater focus on assessment. These two important findings were subsequently used to delve more deeply into the reasoning and arguments behind these changes. For this reason, the third and fourth articles only present findings from the intervention.

Article three specifically addresses the question of how the pre-service teachers plan, conduct and reflect on the teaching of a specific learning aim. Article four addresses how the pre-service teachers planned, conducted and reflected on the assessment of the learning aim that was researched in article three. Both articles three and four present findings that support the findings presented in articles one and two. However, they also nuance these findings by arguing that the results indicate that the pre-service teachers’ understanding of teaching a learning aim and assessment may be superficial and lacking strong connections.

Through discussions of the findings from the four articles, the conclusion is that the use of Lesson Study combined with Content Representation may possibly affect pre-service physics teachers’ potential to start developing Pedagogical Content Knowledge during field practice in teacher education. This conclusion is partly based on research results that indicate that this combination, in a better way than what is typically found, may help pre-service teachers to combine theory and practice. However, the results also questioned the depth of the pre-service teachers' expressed knowledge during the intervention. This indicates that the Lesson Study and Content Representation approach during field practice might not influence the pre-service teachers' Pedagogical Content Knowledge as deeply as hoped for.

Included articles

Article 1
Juhler, M. V. (2016). The use of lesson study combined with content representation in the planning of physics lessons during field practice to develop pedagogical content knowledge. *Journal of Science Teacher Education*, *27*(5), 533–553.

Article 2
Juhler, M. V. (In review). The use of Lesson Study combined with Content Representation during reflection on a taught field practice lesson to develop Pedagogical Content Knowledge. *Nordina.*

Article 3
Juhler, M. V., & Håland, B. (2016). The impact of lesson study and content representation on student teachers' science teaching. In B. Hallås & G. Grimsæth (Eds.), *Lesson Study i en nordisk kontekst* (pp. 195–213). Oslo: Gyldendal Akademisk.

Article 4
Juhler, M. V. (In press). Assessment of understanding: Student teachers' preparation, implementation and reflection of a lesson plan for science. *Research in Science Education.*

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1 Introduction

This extended abstract explores field practice training during teacher education in science. Within this context, it tries to explore how the Lesson Study method and the Content Representation tool might affect the development of pre-service teachers' (PSTs') Pedagogical Content Knowledge. One main aim is to see whether this approach can address the problem of combining theory and practice.

1.1 Framing the study

The context

The question of how the professional development of PSTs should happen within teacher education is one that has many stakeholders and one that has received much attention in recent years (e.g. Boyd, Grossman, Lankford, Loeb, & Wyckoff, 2009; Day, 2016; Kind, 2009; Lehesvuori, Viiri, & Rasku-Puttonen, 2011; Mustapha, 2016). One reason for this attention is that policy makers and educational researchers around the world have embraced the idea that teachers are among the most important factors affecting pupils' achievements (OECD, 2005). Therefore, policy makers and teacher educators pose many questions regarding which qualifications teachers need to possess in order to teach a specific subject, and which types of knowledge, skills, and support teachers need to be efficient (Sleeter, 2014).

Currently, many teacher education programs around the world recognize that subject-matter knowledge, general pedagogical knowledge, and Pedagogical Content Knowledge all play a crucial role in the development of efficient subject-specific teachers (Abell, 2000; Sickel, Banilower, Carlson, & Van Driel, 2015). Most teacher education programs also value the practical aspect of learning from experience, providing substantial field practice opportunities, during which the PSTs can practise teaching in authentic classrooms (Russel & Martin, 2007). A general appreciation has also developed for the use of more pupil-centred methods (Peters, 2010). When these elements have been in place, they have been linked to increased pupil outcomes (Canrinus, Bergem, Klette, & Hammerness, 2015).

The problem of fragmentation

Even though all the aforementioned elements (subject-matter knowledge, general pedagogical knowledge, Pedagogical Content Knowledge, field practice and pupil-centred methods) are recognized as being important in the development of efficient teachers, the fact is that efficient teachers also need to have a deep understanding and integration of all the aforementioned elements (Gess-Newsome, 2015; Shulman, 1986). However, there has been a tendency in teacher education to teach these elements in a separated and disjointed manner (i.e. Hammerness & Klette, 2015; Murata, 2011; Nilsson, 2008; Zeichner, 2010). In situations where this is the case, PSTs need to find their own way to transform these various 'knowledges' into a meaningful coherent whole (Bransford, Brown, & Cocking, 2004; Nilsson, 2008). This is one reason why this form of teaching has been shown to have a relatively weak effect on the practices of new teachers (Hammerness, 2013). The problem of separation is also true more locally. In this respect, the Norwegian Agency for Quality Assurance in Education (NOKUT, 2006) and the former Network Norway Council (Norgesnettrådet, 2002), in their evaluation of Norwegian general teacher education, emphasized concerns about the missing connection between subject-matter knowledge, pedagogical competence, and real-life practice in schools.

The teaching of divorced theory and practice is not only the concern of the stakeholders in educational policy, since such effects are also being reported in PSTs' complaints. In these complaints, the PSTs describe courses as disjointed and irrelevant to practice, or as being "too theoretical" with no bearing on what "real" teachers do in "real" classrooms with "real" pupils (Bransford et al., 2004). Furthermore, the same problem has also been reported during field practice, even though one main aim of field practice experience is to connect theory from teacher education with practice (Canrinus et al., 2015; Sundli, 2007).

These are all reasons why teacher education needs to acquire more knowledge about possible ways of combining these different elements. This situation has arisen since research on teacher preparation has generally been insufficiently explored (Cochran-Smith et al., 2015; Haug, 2008; Munthe & Haug, 2009; Murray et al., 2009). Moreover, this is especially true when it comes to the subject of science (Bradbury & Koballa, 2007), which is the subject of focus in this research.

PCK as an answer to the fragmentation problem

In 1986/87, Shulman introduced the idea of Pedagogical Content Knowledge (PCK), by which he defined the sole domain of expert teachers', as opposed to an expert pedagogue or a subject-matter expert. He specifically argued that what sets expert teachers' apart is that they have a deep integration of subject-matter knowledge, general pedagogical knowledge, and how to organize, represent and adopt these to the diverse interest and abilities of learners (Shulman, 1986, 1987). He did this partly in an effort to address the problem of the separation of theory and practice (Shulman, 2015). Since then, more and more educational researchers within science have believed that by focusing on the development of PSTs' PCK during teacher education, a more coherent knowledge base for teaching can be obtained (e.g. Anderson & Mitchener, 1994; Van Driel & Berry, 2012). Furthermore, many current researchers regard the development of PCK, under different definitions, as being the skilful teacher's developmental objective (Appleton, 2008; Berry, Friedrichsen, & Loughran, 2015; Henze, Van Driel, & Verloop, 2008; E. Lee & Luft, 2008; Loughran, Berry, & Mulhall, 2012; Nilsson, 2008; Park & Oliver, 2008).

Within the arena of teacher education, the construct of PCK is of important value. This lies in its potential to define important integrated dimensions of expertise in science teaching that can be used to guide the focus and design of pre-service and in-service teacher education programs. As such, it can be used as a conceptual tool for helping science teachers to construct the specific knowledge they need to be effective teachers (Magnusson, Krajcik, & Borko, 1999). Hence, there is considerable merit, both in relation to research, theory and practice, in exploring ways to bring about the development of PSTs' PCK.

Developing PCK through Lesson Study and CoRe

Within the context of European teacher education, the Lesson Study (LS) method (C. Fernandez & Yoshida, 2004; Lewis & Tsuchida, 1999) and the Content Representation (CoRe) tool (Loughran et al., 2012) have individually been shown as possible means of developing science teachers' PCK (Adam Bertram, 2014; Nilsson & Loughran, 2012b; Padilla, Ponce de León, Rembado,

& Garritz, 2008; Pongsanon, Akerson, & Rogers, 2011; Weiland, Akerson, Rogers, & Pongsanon, 2010). The same applies to other methods, such as cognitive strategies (Kinach, 2002), or peer coaching (Jang & Chen, 2010). One main reason that both LS and CoRe have been found to develop PCK is that they help teachers to connect theory and practice in different ways. How this is accomplished, together with an explanation of each, is further explained in section 2.4.

With regard to LS, however, recent research has revealed that newcomers to the method do not seem to focus enough and go into enough depth during the planning process, which prohibits their potential for PCK development (Yoshida & Jackson, 2011). Therefore, it seems reasonable to assume that newcomers need a tool to help them to scaffold this difficult process, which is in line with present research (Amador & Weiland, 2015; Lewis & Perry, 2014; Yoshida & Jackson, 2011). The tool CoRe seems to be able to achieve exactly this since it combines learning aims with pedagogical prompts in a systematic way (Nilsson & Loughran, 2012b).

The research gap

LS has been used in Japan as a professional development method for over 140 years (Ronda, 2013). However, it was only in the late 1990s that Lewis and Tsuchida (1997) introduced the method into the USA. After the publication of *The Teaching Gap* (Stigler & Hiebert, 1999), LS started to gain momentum within teacher education in the USA and subsequently gradually found its way into Europe. As a consequence, little research exists within the European context. Furthermore, most of the research carried out on LS and published in English primarily focuses on the teaching of mathematics, thereby leaving the subject of science relatively unexplored (Banilower et al., 2013; Dotger, 2015). Of this corpus of research, relatively little focuses on the potential of LS to influence teachers' development of PCK during teacher education (i.e. Pongsanon et al., 2011; Weiland et al., 2010). Furthermore, among the existing research, only a few studies have attempted to build a theoretical framework of how LS impacts the knowledge teachers need to become experts (Lewis, Perry, & Hurd, 2009).

On the other hand, CoRe has been developed as part of scientific research that aims at developing and depicting PCK (Loughran et al., 2012). This means that some groups have investigated how CoRe influences PCK development in science, e.g. Loughran's group in Australia (Loughran, 2002; Loughran, Mulhall, & Berry, 2004, 2008), Hume's group in New Zealand (A. Hume & Berry, 2013; Anne Hume, 2011) and Nilsson in Sweden (Nilsson, 2011; Nilsson & Loughran, 2012b). These groups have produced some research, although only a small part of it covers teacher education field practice. However, and most importantly, none of the above-mentioned researchers have tried to use CoRe as a scaffolding tool during a LS approach to develop PSTs' PCK.

The LS approach and the CoRe tool have both been shown to be promising in developing PCK within science (Adam Bertram, 2014; Nilsson & Loughran, 2012b; Padilla et al., 2008; Pongsanon et al., 2011; Weiland et al., 2010), while the development of PCK might help PSTs to connect theory and practice. These are two good reasons for conducting further research within both fields. However, research on the combination of LS and CoRe within field practice may be especially important. One hypothesis of the present study is that the combination of these approaches could create a synergy effect that could potentially help PSTs to fully engage with LS, thereby furthering their PCK development. This study attempts to investigate this important research gap.

Which aspects to engage with

Within this proclaimed research gap, several scholars call for the need for specific research within this field. For instance, several researchers call for studies that examine the preparation and teaching of a whole topic and the reasons for that approach (e.g. De Jong, Van Driel, & Verloop, 2005; Hall & Smith, 2006; Padilla et al., 2008). Other researchers ask for research in field practice that looks into teachers' thoughts and actions, and how these are connected to changes in instructions and plans, and what effect this has on learning outcomes (Hall & Smith, 2006). Heritage et al. (2009) call for research on PSTs' ability to adapt instruction based on the assessment of pupils' knowledge and understanding during practice. Other researchers point to the need for research on the influence of mentor teachers on PSTs (Bradbury & Koballa, 2007; Van Driel, De Jong, & Verloop, 2002). All of the aforementioned elements would be covered if LS and CoRe were introduced and used during teacher education field practice, which adds to the importance of the present research.

1.2 The research question and how it was answered

To lead the investigation into the presented research gap, the following research question is posed:

> *"How does the use of Lesson Study combined with Content Representation affect pre-service science teachers' potential to start developing Pedagogical Content Knowledge during field practice in teacher education?"*

This question was investigated through a time-lagged design experiment, looking into how physics PSTs' field practice differs between a control condition and an intervention. During the control condition, field practice was conducted according to the National Guidelines (Ministry of Education, 2010). During the intervention, in contrast, LS combined with CoRe was introduced and used throughout the field practice. During both conditions, researchers followed groups of PSTs and their mentor teachers as they planned, conducted, and subsequently reflected on a lesson. The above research was carried out as a part of a larger research project called Teachers as Students (see further descriptions in section 3.1).

Since the act of planning, conducting and reflecting is a highly complex activity in which teachers must apply knowledge from multiple domains (Magnusson et al., 1999), and since it applied to two conditions, the present research contributes to recent academic discussions in several ways. First of all, it contributes to how PSTs handle and connect several complex domains. Second, it contributes to the discussion of how PSTs' knowledge within these domains develops and is influenced by the field practice experience. Third, in an effort to connect theory and practice, it contributes to the discussion of how field practice may be changed. These are all important factors needed to develop powerful educational programs.

1.3 The structure of the extended abstract

To study PSTs' learning to become skilful teachers within the domain of science, one first needs a theoretical framework from which to understand learning and from which to approach the problem of combining theory and practice. This is approached in Chapter 2, 'Theoretical background', which focuses on how research findings and contemporary learning theory add to researchers' understanding of how learning develops, and can be developed further, within the domain of science teacher education. First, it looks into the challenge of developing the knowledge teachers need to become experts and argues why PCK might represent a powerful vision for teacher education in this respect (section 2.1). Second, it describes how learning can be understood within the domain of science teacher education and positioning this research within that field (section 2.2). Third, it describes PCK in detail both as a useful heuristic for defining a skilful teacher within science and as a means of addressing the problem of combining theory and practice (section 2.3). Lastly, two possible means of bringing about PCK development are discussed, namely the LS method and the CoRe tool (section. 2.4).

Chapter 3, 'The research process', describes the methodology and the research process behind collecting the data required to answer the research question. First, it introduces the overarching research design, developed to answer the research question in the light of a specific context and the theory previously presented (section 3.1). Second, a detailed account of the two research conditions is provided, as well as an account of the data collection and participants involved, as related to the overarching research design (section 3.2). Third, the specific methods of analysis are presented and discussed in light of the overarching research design and data collection (section 3.3). Fourth, the quality of the study (section 3.4), together with ethical considerations (section 3.5), is discussed in light of sections 3.1, 3.2 and 3.3.

Chapter 4 aims to show how the results collected for this study, across the four articles produced, can be used to show overarching tendencies. First, it presents and combines the research results from the first two articles, which compared the two conditions (section 4.1). Second, it presents and combines the research results from the third and the fourth articles, which in detail researched the planning, conducting and reflection on a lesson during the intervention (section 4.2).

In Chapter 5, the individual results, and those considered in combination, are discussed in three sections (section 5.1). Second, the above two discussions are used to debate overarching issues and tendencies described throughout all of the four articles (section 5.2). Finally, limitations (section 5.3), conclusion (section 5.4), and implications for future research (section 5.5) are all discussed.

2 Theoretical background

In this chapter, the theoretical background and perspectives used in this research project will be introduced. First, it looks into the challenge of professional development, especially why theory and practice are separated in many cases. This, in turn, indicates the need for a coherent framework for teacher education. Second, it explores how contemporary learning theory within science adds to researchers' understanding of learning development, which consequently leads to the positioning of the Ph.D. project within the field. Third, in light of the challenges and learning theoretical perspectives presented, there is a discussion of what expert teacher knowledge is and how this develops. Finally, in light of all the previously-presented perspectives, two possible means of bringing about expert teachers' knowledge are discussed, namely LS and CoRe.

2.1 *The challenge of professional development as depicted through international and national research*

This section aims to investigate current practices in teacher education, mentoring and research on PSTs' professional development in order to understand why theory and practice are often fragmented within the Norwegian context, as outlined in section 1.1. The section first presents research uncovering challenges in learning how to teach. Second, it describes examples of powerful teacher education programs that seem to address these challenges. Third, and in light of the previously presented knowledge, there is an examination of why the problem of fragmentation still exists within a Norwegian context. These investigations combined indicate the need for a framework that can create a coherent understanding of the field, while also be used to create coherence within the field. Together, they thus create a unifying vision and understanding for twenty-first century teacher education. In this regard, it will be argued why the PCK framework represents such a powerful vision.

2.1.1 The challenges of learning how to teach

The understanding of the nature and problems involved during the scholarship of learning are fundamental to creating conditions where PSTs, teacher educators and mentor teachers can actively, critically and reflectively be engaged in developing teachers' expert knowledge (Lovat & Clement, 2008). In this context, researchers have found several perennial challenges in learning to teach (Darling-Hammond, 2006; Loughran, 2016; Loughran, Korthagen, & Russel, 2013). Three challenges stand out as crucial: 'Apprenticeship of observation', 'Challenge of enactment' and 'Challenge of complexity'. The coming sub-section aims try to provide insights into the scholarship of learning related to these challenges.

Apprenticeship of observation

The act of learning to teach requires that PSTs learn to understand teaching in ways quite different from their own experiences as pupils. Lortie (1975) describes this as the challenge of 'apprenticeship of observation'.

The main problem is that PSTs subconsciously seem to resist adopting approaches different from those of their own experiences (Pajares, 1992; Richardson, 1996; Sarason, 1990). However, PSTs' own experiences do not allow them to understand the teacher's intentions or personal reflections, e.g. on the selection of goals, the preparation of lessons, or how they are assessed (Lortie, 1975). Furthermore, teaching nowadays differs vastly from prior methods and stances, e.g. teaching with a transmissive view or teaching for memorization (Darling-Hammond, 2006). These findings point to the importance of challenging the PSTs' beliefs during their education (e.g. Larkin, 2012; Pringle, 2006; Stump, 2010; Uzuntiryaki, Boz, Kirbulut, & Bektas, 2009); the PSTs might otherwise assume that they know how to teach and that all that is required are a few strategies, skills and some technical routines (Bandura, 1986; Hashweh, 1996). However, confrontation alone is insufficient to change the PSTs' conceptual framework (Burgoon, Heddle, & Duran, 2010); they also need to be presented with a new conception that is seen as intelligible, plausible and fruitful (Dana, McLoughlin, & Freeman, 1998; Settlage & 'Dee' Goldston, 2007).

The challenge of enactment

Learning to teach requires that PSTs not only learn to think as teachers, but also to act as teachers. Kennedy (1999) termed this as ‘the challenge of enactment’.

What makes learning to enact a difficult task is that theory is embedded in and inseparable from practice (Schön, 1983). For example, one cannot fully know during the planning phase how different strategies work with different groups of pupils, or how pupils’ behaviour will influence teaching. Therefore, PSTs need to learn to deal with pupils’ behaviour, make quick decisions about difficult dilemmas, and both plan well and be able to alter their plans as unforeseen circumstances occur (Darling-Hammond, 2006). In this respect, inconsistent beliefs and insufficient subject-matter knowledge (SMK) have also been found to negatively influence the enactment of intentions. Specifically, teachers have been found to teach in ways that are different from those they were taught and how they intended during planning (Darling-Hammond, 2006; Harlen, 1997; Van Driel, Verloop, & De Vos, 1998). This is particularly likely to happen if PSTs do not have the opportunity to engage in strong experiences where critical concepts are modelled in practice and deconstructed for further study and understanding (Darling-Hammond, 2006). This is also likely to happen if PSTs learn to base their understandings on collected evidence, actively learn to listen to pupils’ expressed understandings, and use this information to change their teaching (Loughran, 2016).

The challenge of complexity

Quality teaching is complex, messy and without a straight and smooth path (Berry, 2004), contrary to what most outsiders perceive (Loughran, 2016). This complexity occurs within a triangle of relations, i.e. between teacher, pupils and the subject, and these relations constantly change (J. P. McDonald, 1992).

Lampert (2001) therefore argues that teaching will never become routine because challenges, questions and dilemmas constantly shift, and because one teaches various groups of pupils, all of whom have different cultural backgrounds, prior experience, learning needs, strengths, and challenges. It is also because a teacher needs to address multiple goals simultaneously i.e. focusing on content, individual and group needs, and intellectual and social development, while also integrating multiple kinds of knowledge to create effective teaching (Lampert, 2001). Additionally, missions aims of contemporary schools cause teachers to perform more complicated kinds of teaching than in the past. For instance, schools stipulate that teachers are required to fulfil curricular goals, while also preparing pupils to think critically and perform at a high level, something which cannot be achieved by standardized ways of teaching (Darling-Hammond, 2006). PSTs must therefore learn how to understand, handle and respond to this complexity by developing analytic skills that allow for deep investigation of all the individual parts and their connections with each other (Darling-Hammond, 2006)

2.1.2 Powerful teacher education programs

Researchers have studied for a long time what constitutes powerful and efficient teacher programs. These are partly efficient because they address the prior challenges outlined in section 2.1.1. What was found was that powerful and efficient teacher education programs need to promote a clear vision of teachers and teaching; they must be coherent, reflect a shared understanding of teaching and learning among faculty and pupils; and, finally, they must be built around a strong core curriculum that is highly connected to actual teaching practice (Hammerness, 2013; Hammerness & Klette, 2015). This means that core ideas and learning opportunities, in terms of both course work and field practice, are aligned in coherent programs (Darling-Hammond, 2006; Grossman, Hammerness, McDonald, & Ronfeldt, 2008).

Case studies on visions in teacher education programs suggest that a shared conception of purposes could provide faculty and PSTs with common goals, as well as a broader understanding of their work and the meaning of their efforts. This could be particularly important in the overall design of the program since teacher educators who have clearly articulated their overall purposes could in turn develop courses and experiences for PSTs that are consistent with the practices and purposes identified by the teacher education program (Darling-Hammond, 2006; Darling-Hammond et al., 2000). Furthermore, conceptions of powerful teaching that are embodied in a specified vision can promote continued dialogue and reflection about good teaching and learning among a community of faculty, teachers, and PSTs (Hammerness, 2004; Tatto, 1996).

While having a common vision is critical, this alone is not enough. Case studies (Darling-Hammond, 2006; Darling-Hammond et al., 2000; Hammerness, 2006, 2012a, 2012b, 2013), as well as studies of multiple programs (Grossman et al., 2008), have articulated the important role that coherence plays in teacher education programs. Programs which are coherent are purposefully designed and provide a well-structured set of learning experiences that are directly linked to the purposes and goals towards which PSTs need to work. Furthermore, the notion of coherence is interrelated with vision. Common visions of good teaching permeate all coursework and field experiences to create coherence; visions serve as a key factor in defining and aligning the learning experiences (Hammerness, 2013). This link is shown in several empirical case studies of teacher education programs that suggest that having a shared vision is important in order to reduce fragmentation in teacher education programs and for linking theory and practice so that the programs become more coherent (Hammerness, 2004; Tatto, 1996). When teacher education programs have a shared, clear vision that is understood by all the members of the community (faculty, mentoring teachers and PSTs), PSTs' experiences within the program can then become more consistent and coherent. The development of this coherence may, in fact, be particularly important to counter the historical problem of fragmentation between practice and theory (Hammerness, 2013), a problem raised in section 1.1., and which will be returned to in section 2.1.3.

Beyond clear shared visions and a coherent program, teacher education programs also need to present PSTs with opportunities to learn to teach in the context of practice. In this context, exemplary programs have been found to offer a strong core curriculum that is grounded in SMK, general pedagogical knowledge, and PCK (Abell, 2000; Darling-Hammond, 2006; Sickel et al., 2015). For instance, Boyd et al. (2009), through the study of over 30 different teacher education programs, found that PSTs who had opportunities to learn that were 'grounded in practice', or very close to practice, performed better in tests. Similarly, Brouwer and Korthagen (2005), through an iterative design for teacher education that cycled four times between practice and coursework, found that teachers' competence in the classroom was influenced significantly in a positive direction.

The three described aspects of powerful teacher education can, for example, be understood to address the challenges described in section 2.1.1 in the following way. If mentoring teachers in the field practice site are aligned with the theoretical and practical approaches promoted by university coursework as described over, the PSTs would then have a greater opportunity to observe good teaching practice (addressing the challenge of apprenticeship), to learn about how it is enacted (addressing the challenge of enactment), and to receive feedback on their own teaching that could strengthen their understanding of the connections between theory and practice (addressing the challenge of complexity) (Hammerness, 2013).

2.1.3 Fragmentation in teacher education sites and field practice sites within the Norwegian context

Even through 'shared vision', 'coherence' and 'grounding in practice' represent elements of powerful teacher education programs that seem to address challenges in learning how to teach, and that development of coherence may be particularly important to counter the historical problem of fragmentation between practice and theory (Hammerness, 2013), research has often found that this is not easily enacted or implemented (i.e. Hammerness & Klette, 2015; Murata, 2011; Nilsson, 2008; Zeichner, 2010). The following section will therefore examine the causes for this, as they have been found to occur within teacher education sites and field practice sites. As this study is situated within a Norwegian context, the local context will be at the forefront of the examination.

Fragmentation in teacher education sites

Within the Norwegian context, Hammerness (2013) conducted comprehensive research within teacher education sites by conducting interviews with a number of program leaders and teacher educators, as well as studying the official guidelines of many of the teaching education programs. Overall, the research uncovers key ways in which coherence may be lacking in many Norwegian teacher education sites. The arguments are further supported by Afdal (2012), who found that Norwegian curricula reflected a weaker disciplinary foundation and had a more fragmented organization that those in Finland.

Hammerness (2013) found that a majority of program leaders did not have a clear vision for the program, but instead presented their visions fairly briefly and concretely, without much detail or elaboration. This was also reflected in the documents about the programs, which emphasized the administrative features of the program (courses, ETCS requirements, names and course topics) without much focus on a common vision. Hammerness'

(2013) general impressions from the interviews of the teacher educators were that there was an array of individual visions and that what was shared was directly linked to the national guidelines. Some of the problems emanating from these individual visions were uncovered in the interviews. For instance, one teacher educator said that PSTs must experience very different approaches to teaching through the different courses. Another expressed that there were diverging visions between the group of general pedagogues and the group focusing on the teaching of SMK. A program leader expressed that teacher educators within subject-matter areas had a tendency to overlook the connection between subject-matter and practice. Hammerness (2013) also noted that the lack of actual teaching experience amongst the teacher educators who focused on general pedagogy led to them having different visions of teaching from those who did have teaching experience. These findings indicate that PSTs are prevented from gaining a coherent and interrelated understanding of the complexity of teaching.

Hammerness (2013) further found that field practice placement was considered as distinct sites that provided the practice experiences while the universities were the sites of theoretical work. This is the same distinction that Hauge (1994) described almost 20 years ago. Hammerness (2013) also noted that none of the teacher educators mentioned that they could draw upon artefacts from the classroom, examples of pupils' work, videos of classroom teaching, curriculum requirements, or other materials directly related to classroom teaching that could incorporate a practical element to their teaching; they were sceptical about addressing the question of teaching in a practical way. These findings are contrary to research that shows that PSTs cannot learn ambitious teaching practices through field placement alone (Britzman & Greene, 2003; M. A. McDonald, 2005). Furthermore, it has been shown that if PSTs are given the opportunity to practise activities that are close to real teaching, this has a greater influence on their learning as measured by standardized tests (Boyd et al., 2009). This thus indicates that PSTs do not get to understand how to transform teaching in ways that can lead to powerful enactment.

Another way in which teacher education can help PSTs to learn in ways more closely grounded in practice is to provide opportunities to learn about specific instructional strategies that they can enact in the classroom (Grossman, Hammerness, & McDonald, 2009). In this respect, Hammerness (2013) discovered that teacher educators primarily considered their task to be to present PSTs with an array of different methods to prepare them to teach in a variety of circumstances. However, they did not emphasize the ability to make distinctions among the methods or the ways in which content and context might shape one's choice of strategies. This finding is consistent with another recent study on teacher education in Norway that examined preparation for assessment (Tveit, 2009). Furthermore, it is contrary to research that shows that PSTs, in addition to learning approaches, should also learn when, where, how and why to use these particular approaches (Feiman-Nemser, 2001). If these aspects are not included, the PSTs may come away with beliefs that any teaching method is acceptable under any circumstance, as long as they are providing pupils with some general variation in classroom experiences. In turn, this indicates that PSTs are not challenged on their prior beliefs and experiences, which is necessary to address the challenge of apprenticeship.

Mentoring, field practice and the problem of fragmentation

Research has found that strong support of PSTs during field practice is critical for their development and growth (e.g. Bezzina, 2006; Breaux & Wong, 2003; Schuck et al., 2011; Schuck, Aubusson, Buchanan, & Russell, 2012). For instance, when poor support is experienced, it has led to feelings of stress, isolation and being ill-equipped to deal with the realities of the classroom. Strong support, on the other hand, has been found to lead to PSTs being more capable of managing the challenges of the classroom (Schuck et al., 2012), which relates to all the three challenges specified in learning how to teach (section 2.1.1). These are some of the reasons why mentoring within the Norwegian context is regarded as an important approach for securing and enhancing quality (Sundli, 2007). Both nationally and internationally, however, research has revealed that the quality of mentoring varies a good deal and that there is no clear definition of mentoring and what it entails (Schuck et al., 2012; Sundli, 2007). One consequence of this, as further described below, is that the field placement sites, like the teacher educational sites, neither seem to provide the crucial aspect of coherence as described in sub-section 2.1.2.

During field practice, Sundli (2007) argues that Norwegian mentoring may often turn out to be an obstacle to reflective professional teaching rather than an enhancement (Sundli, 2001, 2002, 2007). This is based on extensive research, showing that PSTs are viewed as a resource by parents, colleagues, mentors and school administrations; they are viewed as a kind of assistant who can contribute to a significantly enforced teacher corps during field practice (Sundli, 2007). This is mirrored by research with similar findings in England (Edwards, 1997b). This may be one reason why PSTs who managed to take the role and responsibility of a fully educated teacher from the start were given more credit than those who were more unsure of themselves. Norwegian PSTs may thus feel that they have to hide their identities as novices who need to learn, thereby foreclosing opportunities for e.g. observation, co-teaching or inquiry (Conway et al., 2011; Long et al., 2012), in turn preventing them to address the three challenges described in learning how to teach in sub-section 2.1.1.

Sundli (2007) further found that the majority of time during mentoring sessions was devoted to the adjustment of the PSTs' written plans, so that they fitted into the context of the placement school. It was discovered that conversations were mainly concentrated on practical issues, the pupils' work and behaviour, and how to keep the class quiet. This finding is also echoed by other researchers (Bradbury & Koballa, 2007; Helgevold, Næsheim-Bjørkvik, & Østrem, 2015; Hennissen, Crasborn, Brouwer, Korthagen, & Bergen, 2008; Weiland et al., 2010), as well as my own (Juhler, In review, 2016). Furthermore, mentors' monologues dominated the mentoring sessions, a tendency also found in Germany and Sweden (Brusling, 1991; Skagen, 1999). These monologues were not found to be based on reflections around theory as presented through teacher education, but were rather based on the mentors' own professional experience and lived ideals. Nevertheless, Munthe and Ohnstad (2008) found that most mentors perceived their own work as being of good quality. However, as shown above, mentoring does not seem to bear on deep reflections about transformation of knowledge or about how theory taught during teacher education is connected with practice, which is a problem also reported internationally (Consuegra, Engels, & Struyven, 2014). Instead, teacher education and field practice seem to represent two different discourses. This naturally leads the PSTs to struggle with being taught one perspective during teacher education, while being confronted with a different practice during field placement, in which PSTs have primarily been found to adhere to the discourse of the field practice site (Sundli, 2007). Both these problems have also been previously reported (Smagorinsky, Gibson, Bickmore, Moore, & Cook, 2004). Arguably, this undermines the PSTs' opportunities to understand the complexity of teaching and how theory and practice are connected in a coherent manner.

The above findings have been reported even though Norwegian mentoring teachers and collaborating schools appear to be among the better qualified (Munthe & Ohnstad, 2008), and that a proclaimed goal during field practice is to connect theory and practice (Canrinus et al., 2015; Sundli, 2007). This has led researchers to ponder whether mentor teachers actually perceive themselves as being teacher educators while performing mentoring during field practice (Nilssen, 2009; Ohnstad & Munthe, 2010), which may be a reason why they do not provide the necessary coherence. Researchers are also sceptical about whether spending more time in field practice would actually improve PSTs' learning (e.g. Bullough et al., 2003; Capraro, Capraro, & Helfeldt, 2010; Ronfeldt & Reininger, 2012; Tang, 2003).

2.1.4 Pedagogical Content Knowledge as a vision for teaching and teacher education for the twenty-first century

With these previous sub-sections as a point of departure, researchers, both nationally (Canrinus et al., 2015) and internationally (Cochran-Smith et al., 2015; Darling-Hammond, 2006; Kretchmar & Zeichner, 2016; Laursen, 2015; Taguchi, 2009), therefore argue for the need to address the incoherence between subject-area coursework and field practice, as well as that between subject-area coursework and pedagogical coursework. There is thus a need for an overarching conceptual framework that can be used to understand all of these intertwined and complex challenges, while also providing a powerful vision for twenty-first century teacher education, and in so doing address the challenge of coherence.

One such vision was proposed by Shulman in 1986 and 1987, when he introduced the idea of Pedagogical Content Knowledge (PCK) as an answer to the fragmentation problem (Shulman, 1986, 1987). The main strength of this concept is that it describes a coherent understanding of what an expert teacher's knowledge is and its connection to other important knowledge bases for teaching, namely those of SMK, general pedagogical knowledge, and experience (Shulman, 2015). The PCK framework and its development is described in detail in section 2.3. The introduction of PCK had some important consequences for the educational field of science. First, since it described and defined professional development, it provided a generic goal towards which to work. Second, the framework provided better ideas about how to best support the development of expert teachers' knowledge. Third, it provided a framework that could be used to enable PSTs to understand more deeply the requirements for teaching science (Hashweh, 2013; Loughran, 2014; Schneider, 2015; Shulman, 2015). Some examples follow. For instance, Nilsson and Loughran (2012b) introduced PCK as an academic construct and a conceptual tool to a group of PSTs within science at the start of a semester. The PSTs were asked to use the construct and tool to plan for and assess the development of their own knowledge. The results showed that PCK was an important concept for enhancing PSTs' professional learning, while also providing a window into the nature of how PCK might be better understood and developed. In a similar way, Van Driel and his colleagues (2002) investigated chemistry PSTs' development of PCK when gaining knowledge about pupils' problems as they shifted between the macro and micro levels. They specifically focused on how the different components (workshops, field practice experience and feedback from mentors), contributed to PCK development. They found that classroom experiences (both teaching and observing) had the strongest impact on understanding pupils' learning difficulties. Additionally, they found that an article read and discussed as a part of a workshop which focused on pupils' specific learning difficulties, together with the mentor's guidance, were important sources of learning. The results thus illustrate how the different elements of teacher education and components of expert teachers' knowledge come together to develop PSTs' PCK and provide insight into how the links can be strengthened. Both of the above also provide insight into how the problem of creating coherence can be addressed, even if not specifically stated in the research.

PCK therefore gives and has given teacher education and researchers an encompassing framework to combine, test and challenge what we know about PSTs' challenges when learning how to teach within this complex area (sub-section 2.1.1). Furthermore, by promoting a clear vision and a coherent understanding of expert teachers' knowledge and its development, the framework addresses important aspects described as part of powerful teacher education (sub-section 2.1.2). Finally, by connecting PCK with the core curriculum and teaching practice, it directly addresses the fragmentation problems previously described (sub-section 2.1.3). In sum, it therefore constitutes a powerful shared vision for 21st century teacher education to the point where it is argued that professional development should be based on the notion of PCK (Bausmith & Barry, 2011; Cooper, Loughran, & Berry, 2015; Van Driel & Berry, 2012). However, despite the fact that PCK has proven to be a powerful conceptual framework, more research is needed to gain a greater understanding of the dialectic between expert teachers' knowledge and how best to develop it (Schneider, 2015). This is especially the case since there nowadays exists a diversity of interpretations and definitions within the literature on PCK, a consequence of research placing different values on the different aspects of PCK (Abell, 2008; Shulman, 2015). Therefore, this study positions itself within the complexity of the context depicted above and builds on the PCK framework as a way to understand how to push PSTs' professional development further during field practice.

2.2 Understanding learning within the domain of science teacher education and the positioning of the research within the field

This subchapter has three aims. The first is to investigate contemporary learning theory in order to gain an understanding of learning and its development as understood within the field of science teacher education. This investigation is necessary since there are numerous views on this matter (Cobb, 2005), and since researchers have used and developed the PCK concept from different theoretical standpoints (Kind, 2009; Park & Oliver, 2008). The second aim is to describe two major trends, namely the cognitive and the social/socio-cultural theoretical perspectives, which both contribute to the understanding of learning within the field. The third aim is to position this study within these theoretical perspectives.

2.2.1 Understanding learning and its development within science education

Within the domain of science teacher education, the most accepted and used paradigm from which to understand learning is constructivism. Briefly defined, this is the belief that learning is actively constructed. One reason that constructivism has reached this position is that it can explain the mental and social processes leading to learning in a much better way than prior theories, which mainly relied on a transmissive view of learning, (Blumenfeld, Marx, Patrick, Krajcik, & Soloway, 1997). Another reason is that the constructivist view of learning better aligns with the nature of science, namely how it is defined and how it develops (Driver, Asoko, Leach, Scott, & Mortimer, 1994).

Within this paradigm, two major trends have been identified. The first is the generally accepted cognitive view that builds on the notion that pupils actively construct knowledge in an effort to restore coherence to the worlds of their personal experience. The second trend, in contrast, emphasizes the socially and culturally situated nature of activity, and reflects a disillusionment with an individualistic focus (Cobb, 2005). These two perspectives appear to provide conflicting views and both claim hegemony for their view of the understanding of learning and knowing. According to Sjøberg (2010), the dispute is directed at three main questions. First, is the mind located in the head or in the individual-in-social-action? Second, is learning primarily a process of active cognitive reorganization or a process of enculturation into a community of practice? Third, are symbols a means by which pupils express and communicate their thinking or are they carriers of either established meanings or of a practice of intellectual heritage?

A forced choice between these two perspectives seems unavoidable and in fact is a choice many researchers make (Cobb, 2005). Yet contemporary theorists, such as such as Cobb (2005) and Illeris (2009), argue that these two perspectives are in fact a part of a whole and that both are necessary in order to acquire a coherent understanding of learning. This view is best expressed by Illeris when he states that a fundamental condition for understanding learning is that it has to be understood as:

> *The integration of two very different processes, namely an external interaction process between the learner and his or her social, cultural or material environment, and an internal psychological process of elaboration and acquisition. Many learning theories deal only with one of these processes, which of course does not mean that they are wrong or worthless, as both processes can be studied separately.*

However, it does mean that they do not cover the whole field of learning (Illeris, 2009, pp. 8–9).

The present study agrees with the view expressed above. As this has implications for the understanding of knowledge throughout this extended abstract, a further investigation into this conception of learning is warranted.

Based on the above view, Illeris (2009) first defines learning as: "Any process that in living organisms leads to permanent capacity change and which is not solely due to biological maturation or ageing".

From this definition, together with insights gained from a wide selection of the best recent theories, Illeris argues that the processes involved in learning can be described through the model depicted in the following Figure 1.

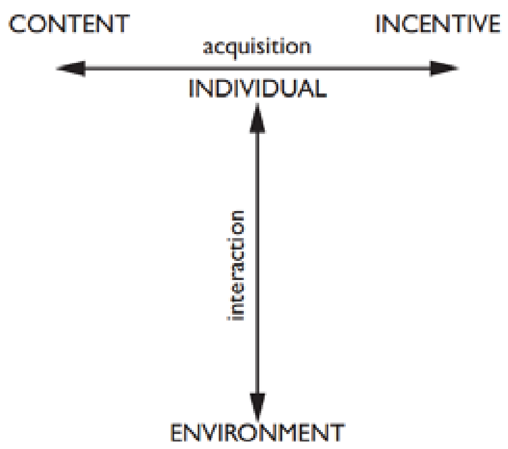

Figure 1: The fundamental processes of learning (Illeris, 2009a, p. 9)

In this model, the vertical double arrow represents the interactions between the *environment* and the *individual*. The *environment* provides the general basis and is therefore placed at the bottom. The *individual* is focused on the specific learner and is therefore placed at the top. In addition, a horizontal double arrow is added. This represents the psychological internal acquisition processes and is therefore placed at the top. The internal process is represented by a double arrow since it consists of the integrated interplay between two equal psychological learning functions. The first is the function directed at managing the learning *content*, as shown on the left. The second is the *incentive* function that provides and directs the necessary mental energy that runs the process, as shown on the right. Together, these two double arrows span out a triangular field between three angles, each of which depicts a dimension of learning. Illeris' core claim is that these three dimensions are always involved in the process of learning (Illeris, 2009).

These dimensions are connected to the development of competences. Illeris (2009, pp. 10–11) describes the *content* dimension as concerning what is learned (knowledge, skills, opinions, insight, meaning, attitudes, values, ways of behaviour, methods, strategies, etc). Functionality is the aim of this dimension, which is brought about by the learners' endeavour to construct meaning and the ability to deal with the challenges of practical life. The *incentive* dimension is about the elements that allow learning to take place. These are feelings, emotions, motivation and volition. The ultimate goal of these elements is to secure continuous mental balance in the learner, which simultaneously develops a personal sensitivity. The *content* and *incentive* dimensions are always initiated by impulses from interaction with the *environment* dimension, and then integrated into the internal process of elaboration and acquisition. The impulses may take place as perception, transmission, experience, imitation, activity, participation, etc. The aim is to serve as personal integration into communities, society and the culture present therein, which thereby strengthens the sociality of the learner. Consequently, the learning *content* is always in a way "obsessed" with the *incentives* at stake. These could be desire, interest, necessity or compulsion. Similarly, the *incentive* dimension is always influenced by the content in the sense that new information can change the *incentives* (Illeris, 2009).

The learning theoretical perspective described above specifically represents a view in which it is not simply a question of choosing between a purely cognitive or social/socio-cultural construction of knowledge, since both contribute important aspects about this process. This has two important implications for this study. The first is that, like most constructivist research, the claim of 'pure´ social constructionism, namely that learning and other mental processes are only social and not individually produced, cannot be accepted (Illeris, 2007; Sjøberg, 2010). The second is that research knowledge within both fields should be used to inform this study. In relation to the latter, a description of the two perspectives is necessary, including their research contributions, which is provided in the following sub-section.

2.2.2 Two trends and their research contributions

This sub-section will briefly outline the cognitive and social/socio-cultural perspectives. Following this, the main research findings based on these perspectives will be used to shed further light on the challenge of developing the knowledge needed to become an expert teacher in the light of the problem of fragmentation.

Within a cognitive tradition, knowledge construction is viewed as an active cognitive act in which the individual receives information, interprets it, and then either fits it in with and adds the information to already existing schematics, or has to reorganize the pre-existing schematics in order to fit in the new information. In this way, knowledge development takes place through discrete changes (Ertmer & Newby, 1993). Within these schematics, concepts are then placed in an orderly way, dictated by how they relate to each other, thus making large connected cognitive networks (Kaufhold, 2002). This has important implications for education. First of all, it means that learners can acquire knowledge and skills separately. Second, the building of connections between learning objectives should be a central part of teacher education programs. Third, teachers need to pay attention to the learners' prior conceptions/misconceptions, as these play an integral part in the learning process (Driver et al., 1994).

From the perspective of social constructivism, the construction of knowledge is viewed as happening through social interaction with peers, when applying ideas in practice and through reflection, and through the modification of these ideas (Angell et al., 2011). Thus, knowledge development is revealed as a feature of both reflection in and on action (Schön, 1983, 1987). Cognitive development is further influenced by interaction with a specific culture: cultural history, social context and language. As such, culture is seen as providing the learner with the cognitive tools needed for development. Therefore, it is important to focus on how teachers and other learners can aid and assist in the process of understanding the concepts within that specific context (Bruner, 1985).

From the perspective of socio-cultural theory, knowledge is essentially understood as an ever-changing cultural product in a process from social to personal knowledge (Murphy, Alexandre, & Muis, 2012). The development of knowledge is bound to a specific context in which knowledge is distributed. The aim is to move from peripheral participation to becoming a fully accepted member of the cultural practice. Within the specific context, learning is mediated by both psychological and physical tools. The most important psychological tool is language (Cobb, 2007). Implications for teaching are stressed by the situated perspective (Abell, 2007). This perspective underpins, on the one hand, that the community has to fully accept the PSTs, i.e. not to consider them as newcomers. On the other hand, it underpins that PSTs have to see themselves as members of the community. This requires the PSTs to take responsibility for their own actions in that position, including their use of knowledge and skills (ten Dam & Blom, 2006).

Research within the cognitive constructive paradigm has found several aspects that prohibit the integration of theory and practice during field placement. One aspect is that teachers' belief systems and orientations are persistent to change (Appleton & Asoko, 1996). For instance, one can still find teachers who cling to a transmission belief and mode of teaching and learning (Louie, Stackman, Drevdahl, & Purdy, 2002). A second aspect is that teachers have been found to hold many of the same naive ideas as their pupils. Unaware of holding these ideas, they instead perpetuate them (Gess-Newsome & Lederman, 1999). A third aspect is that teachers generally lack SMK (e.g. Loughran et al., 2008), and what knowledge they possess is not structured in a coherent or connected way (Gess-Newsome & Lederman, 1999). Furthermore, much of this knowledge is inert (Kersting, Givvin, Sotelo, & Stigler, 2010). As a consequence, teachers present information in the form of disjointed facts without organization and connectedness (Gess-Newsome & Lederman, 1999), and struggle to collect the necessary evidence for assessment (Morrison & Lederman, 2003). A fourth aspect suggests that teaching puts a high cognitive demand on teachers (Kagan, 1992). Teachers therefore tend to reduce its complexity by developing tacit knowledge routines aimed at filtering out extraneous details; this results in their focus on pedagogical strategies and general management (e.g. Kagan, 1992; Weiland et al., 2010). Teachers also plan activities that are designed to give them control over the learners.

However, the learning potential of the activity is consequently reduced (Black & Harrison, 2006).

Many of these aspects are intended to be addressed through the social and cultural interactions during the PSTs' field placement. However, research within these two paradigms has found two important reasons preventing this from happening. One is that the discourse between field placement and teacher education has often been found to be at odds and that PSTs, in an effort to fit in, mostly adhere to the discourse of the field placement school (Tobin, Tippins, & Gallard, 1994). The second is that mentor teachers working in the field placement schools do not adhere to the discourse of teacher education. This is the case even though they have been able to take part in this discourse during mentor teacher education, and even though one of the main functions of the mentor is to help PSTs to combine the theory presented during teacher education with practice (Sundli, 2001, 2007). The consequences of both are that PSTs primarily focus on curricular coverage, pedagogical strategies, classroom management and time management during their field practice placement, meaning that theory and practice are not combined (Burn, Hagger, Mutton, & Everton, 2000; Gess-Newsome & Lederman, 1999; Levin, Hammer, & Coffey, 2009; Weiland et al., 2010).

This has been explained by the fact that mentor teachers' knowledge is primarily developed through classroom experience. Hence, much of their knowledge is about what 'works' but not why, and these experiences are tied to a specific context (Hiebert, Gallimore, & Stigler, 2002; Loughran, Mulhall, Berry, Gunstone, & Phillippa, 2000). Furthermore, although mentor teachers may have a wealth of knowledge about both the content and pedagogy appropriate for science teaching and learning, much of this knowledge is tacit, thus making it difficult for them to recognize and express their thoughts during mentoring (Edwards, 1997a; Gess-Newsome, 1999; Korthagen & Kessels, 1999; Loughran et al., 2000).

2.2.3 Positioning of this study within the field

As described in sub-section 2.2.1, Illeris (2009) constructed a more coherent understanding of learning within the constructivist context by merging together empirical evidence from e.g. cognitive, social and socio-cultural research. This covers a large field in which the present study needs to position itself.

According to the main research question, the aim of this research is to study PSTs' knowledge as it develops through the social interaction during field practice as unfolded within the cultural context of science teacher education. What is specifically emphasized is the development of PCK through group work, the social constructivist perspective, which means that this research places itself closest to that of the social dimension, as described by Illeris (see Figure 1, p. 21). Change is thereby sought to be implemented by means of LS and CoRe (described in detail in section 2.4), both of which can be described as cultural tools. The mechanism of change, according to Illeris' theoretical model, can thus be understood as one that is aimed at altering the cultural and social context, which in turn has the possibility to promote the PSTs' PCK development through interaction.

The above positioning and thought mechanism of change has implications for this research. First of all, it influences the choice of the PCK framework used for this study, as described in section 2.3. Second, it has been used when studying how this knowledge can be developed through LS and CoRe (section 2.4). Third, it has influenced the thinking around and conducting of the research process (Chapter 3), which has naturally affected the results gained from the investigation (Chapter 4). Finally, it has also influenced how the results are discussed in Chapter 5.

2.3 Expert teachers' knowledge: Definition and development

As described above, constructivist learning theories have several important implications for understanding learning within the domain of science teaching. However, in addition to general learning theories, one needs a useful heuristic for defining a expert teacher's knowledge within science (Grossman, 1990). This heuristic furthermore needs to be able to aid the study of the development of this knowledge. It also needs to be able to address the problem of combining theory and practice, as previously examined. In the following, I will argue why PCK constitutes such a theory. I will then argue why such a theory needs to be subject-specific and I will argue for the use of the model for science PCK proposed by Magnusson et al. (1999). Finally, I will take a critical view of the applied model in the light of a recently developed unified model for science since the unified model addresses several issues found in that of Magnusson et al. (1999).

2.3.1 The missing paradigm and the development of Pedagogical Content Knowledge

In 1986, Shulman addressed the fragmentation problem by describing the 'missing paradigm' within the domain of learning theories, namely the absence of research and thought directed at how content knowledge and pedagogy relate to each other when teaching. In this regard, he strongly advocated that these two aspects should be integrated:

> *Mere content knowledge is likely to be as useless pedagogically as content-free skill. But to blend properly the two aspects of a teacher's capacities requires that we pay as much attention to the content aspects of teaching as we have recently devoted to the elements of teaching process* (Shulman, 1986, p. 8).

As a consequence, Shulman (1986) developed the idea of 'Pedagogical Content Knowledge' (PCK), which he believed was the sole domain of an expert teacher, that which sets him apart from the pedagogue or the subject-matter expert, namely a domain where content and pedagogy are integrated. Shulman defined PCK as:

> *The most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations in a word, the ways of representing and formulating the subject that make it comprehensible to others… Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that pupils of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons* (Shulman, 1986, p. 9).

One year later, Shulman (1987) incorporated a more social aspect by linking PCK development to the wisdom of practice through his model of pedagogical reasoning and action. This was done in an attempt to understand how PSTs commute from the status of learners to that of teachers. Figure 2 describes this process. In this context, it is important to know that even though the steps are presented in sequence, they are not meant to represent a set of fixed steps. They could occur in a different order, or not occur at all.

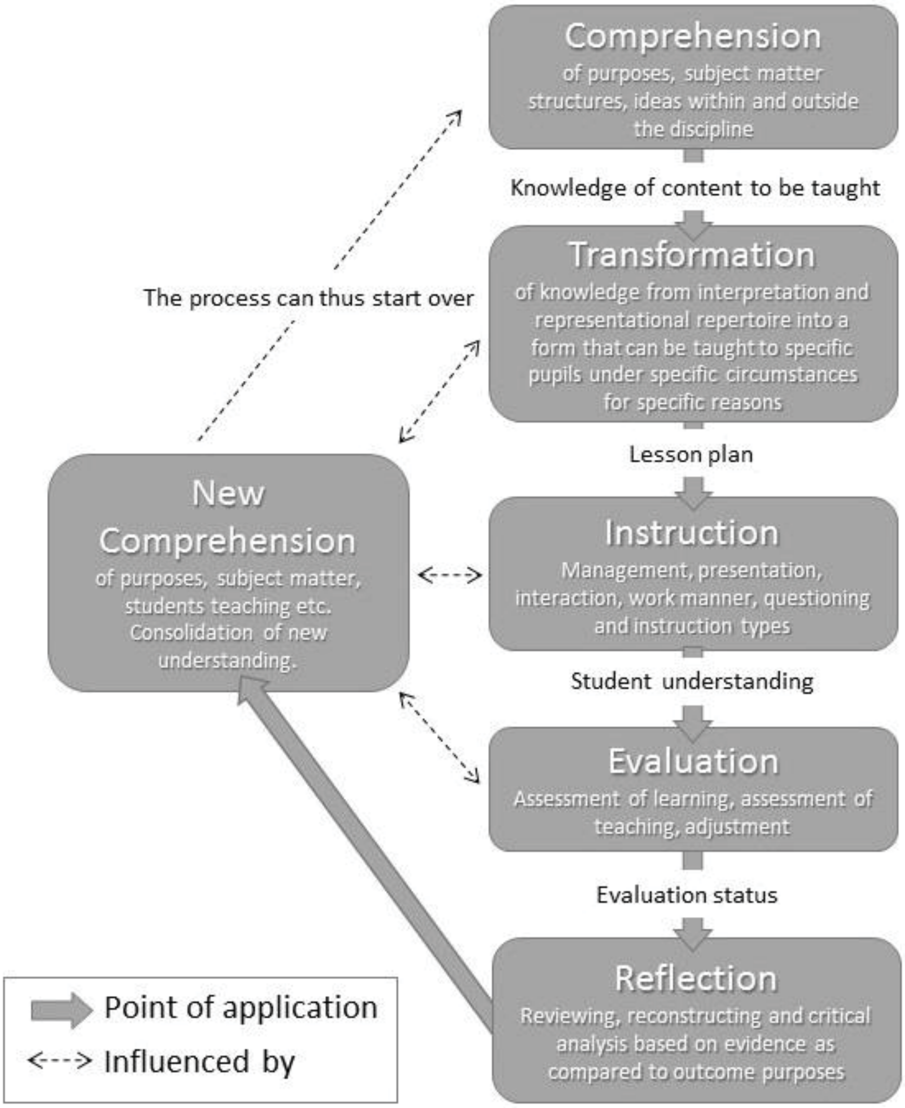

Figure 2: Schematic representation of Shulman's (1987) model of pedagogical reasoning and action, based on a figure presented in Nilsson (2009).

Shulman (1987) describes the first step towards building the knowledge needed to become an expert teacher as obtaining a critical ‘Comprehension’ of the subject to be taught. This includes a level of understanding that enables the teacher to teach the subject, the understanding of several ways of teaching, the understanding of how the given idea relates to other ideas within the subject and between subjects, and the purpose of teaching this idea. During this step, it is difficult to distinguish a teacher from non-teaching peers, while during the ‘Transformation’ stage the differences are clearer.

During ‘Transformation’, the comprehended ideas must be transformed so that they move from personal comprehension to preparing for the comprehension of others. This process includes critical interpretations of, e.g. texts and educational purposes and goals, identification of key aspects, structuring and segmenting the material, consideration of representation forms, e.g. through analogies, selecting specific instructional methods, and adapting the former to the general and specific characteristics of specific pupils, as well as the desired learning outcomes. This typically results in lesson plans and a set of strategies to present the unit.

The next activity is ‘Instruction’. This includes crucial aspects of pedagogy: organizing and managing the classroom, presenting clear explanations, assigning and checking work, interaction with pupils, answers and reactions, and praise and criticism. All of these build on the understandings gained through the prior two steps. Closely linked to ‘Instruction’ is ‘Evaluation’ of the desired outcomes, which can be directed at both the pedagogical aims or the subject-matter aims.

‘Evaluation’ covers both formative and summative assessment methods and relates strongly to teacher ‘Comprehension’ and ‘Transformation’ as described above, thus creating a clear link between the two.

After the lesson, the teacher goes through the ‘Reflection’ step. This is where the teacher looks back at the prior steps and reconstructs, reenacts, and/or recaptures the events, the emotions, and the accomplishments. It is where comparison between intentions and thoughts emanating from the prior steps is reasoned upon. It is through this process that a professional teacher learns from experience, something that can be done alone or together with others. After going through this process of teaching acts that are “reasoned” and “reasonable”, the teacher achieves ‘New comprehension’.

This 'New comprehension' entails both the purpose of and the subjects to be taught, as well as the pupils and the pedagogical process. However, this 'New comprehension' does not occur naturally since specific strategies for documentation, analyses and discussion are needed in order to gain this 'New comprehension' (Shulman, 1987).

Shulman's way of linking professional development with the model of pedagogical reasoning and action thus shows that to understand professional development, all six components of this model need to be considered. Therefore, this has been used to frame and link the four articles upon which this extended abstract is based (see section 3.2 for further details). Shulman has provided a definition and a starting model of what constitutes a skilful teacher's knowledge, namely PCK. However, to be usable as a tool to elucidate knowledge about PSTs' science learning, one needs a model that covers this specific subject. The choice of such a model must rely on one's conceptualization of learning, together with the aim of the study. In this regard, two important conceptualizations of PCK exist historically and thus need to be considered. This is the objective of the next sub-section.

2.3.2 A subject-specific model: Integrative or transformative?

In the aftermath of Shulman's publication of the notion of PCK, many researchers have used and developed PCK models that suited their perspectives on learning theory and which were subject-specific. As a consequence, there are currently multiple perspectives on what PCK is and more than one legitimate and fruitful way of thinking about PCK (Shulman, 2015). An overview of the best-known models within science developed until 1999 can be found in Appendix A. This overview builds on reviews carried out by Park and Oliver (2008) and Kind (2009).

The developed models disagree on three main aspects. First, they disagree on which components to include as PCK. Second, they disagree on which components to consider as part of a teacher's professional knowledge base without being part of PCK. Third, they disagree on which components are not part of teacher's professional knowledge base. This debate boils down to one fundamental question: is the development of PCK integrative or transformative (Park & Oliver, 2008)? Gess-Newsome and Leaderman (1999) explain the difference between an integrative and a transformative view by using the analogy of chemical elements. In an integrative model, the different chemical elements retain their individual identities when mixed. However, on a macroscopic level they cannot be distinguished from each other. On the other hand, in the transformative model the different individual elements react when mixed, thus inextricably combining into a new compound.

An investigation of these models shows that scholars who include one or several of the components 'Subject-matter knowledge', 'Contexts for learning' and 'General pedagogy/Classroom management' as part of PCK, hold an integrative view (e.g. Cochran, DeRuiter, & King, 1993; Fernandez-Balboa & Stiehl, 1995; Koballa, Gräber, Coleman, & Kemp, 1999; Marks, 1990; Tamir, 1988; Veal & MaKinster, 1999). Since this positioning is the one that includes the context for learning, it can be argued that the present research leans towards that of the socio-cultural tradition. For instance, Cochran et al. (1993) argue that PCK includes the awareness of the environment in which teachers work, and that this environment is influenced by political, social, cultural and physical factors. In contrast, scholars who do not include these components in PCK, thereby aligning with Shulman's (1986) original definition, adopt a transformative view (e.g. Geddis, Onslow, Beynon, & Oesch, 1993; Grossman, 1990; Magnusson et al., 1999; Smith & Neale, 1989; Tamir, 1988). It can thereby be argued that these scholars' research leans more towards that of the cognitive tradition.

This study has chosen to use the model by Magnusson et al. (1999), 'Components of PCK for science teaching' (See Figure 4, next sub-section). The reasons for this, in relation to the discussion above, are as follows. First, this model builds on a transformative view of learning which aligns better with the research aim and focus explained in sub-section 2.2.3. The transformative models, as opposed to the integrative ones, clearly distinguish the professional teacher from the subject-matter or pedagogical expert, which is a necessary distinction (Shulman, 1986). This separation is supported by contemporary research (Gess-Newsome, 2015; Van Driel, Berry, & Meirink, 2014). It can also be argued that integrative models would have less explanatory power when used to analyse learning since they incorporate very broad and generic concepts. In comparison, Magnusson et al.'s model provides a clear map, identifying categories of knowledge to pay attention to, which is a strength (Friedrichen, 2015). These are some of the reasons why this model was the most used within science teacher education until 2012, even though researchers used it under different conceptualizations (Gess-Newsome, 2015). The next sub-section will explore this model in more detail.

2.3.3 A model of PCK for science

In Magnusson et al.'s (1999) view, *"The defining feature of PCK is its conceptualization as the result of a transformation of knowledge from other domains"*. These domains (or bases) are 'Subject-matter knowledge and beliefs', 'Pedagogical knowledge and beliefs', and 'Knowledge and beliefs about context'. These domains are represented by the shaded boxes in Figure 3. The relationship and direction between the knowledge domains and PCK are illustrated by terms on the lines and the arrows at the ends. The arrows aim to show the transformation from the three knowledge domains resulting in PCK. However, it also shows that the resulting knowledge can in turn spur development of the main domains (Magnusson et al., 1999, p. 96).

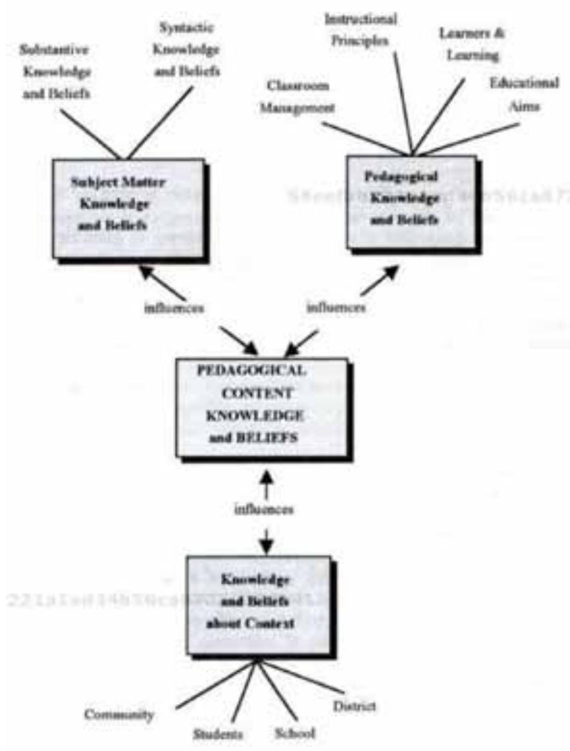

Figure 3: A model of the relationships among the domains of teacher knowledge (Magnusson et al., 1999, p. 98).

Magnusson et al. stay close to Shulman's original definition of PCK when defining PCK for science as follows:

> *… a teacher's understanding of how to help pupils understand specific subject-matter. It includes knowledge of how particular subject-matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction* (Magnusson et al., 1999, p. 96).

In relation to this definition, Magnusson et al. (1999) developed their model 'Components of PCK for science' (Figure 4). This model, in addition to Shulman's (1986) originally proposed components, c) 'Pupils' understanding' and (d) 'Instructional strategies', includes (a) 'Orientations to science teaching, (b) 'Curricular knowledge' and (e) 'Assessment'. The inclusion of these categories was based on research conducted by Grossman (1990), Smith and Neale (1989), and Tamir (1988). This research suggested that the three additional components were necessary in order to distinguish the teacher from the subject-matter expert or pedagogy expert, and to increase the explanatory power of the model. To further add to the model's explanatory power, the different components are presented as they were mutually exclusive (Magnusson et al., 1999). This is a notion most scholars accept, since they need a useful model for analysis (e.g. Kellner, Gullberg, Attorps, Thorén, & Tärneberg, 2010; Park & Oliver, 2008). Magnusson et al. (1999) further elaborate that the lines between the components are fuzzy in reality due to their close links.

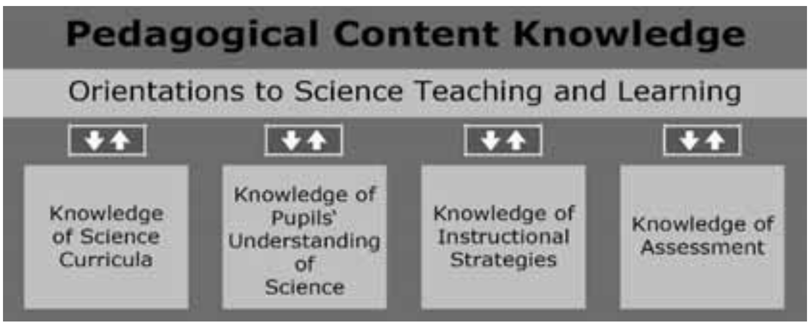

Figure 4: Components of PCK for science teaching (Magnusson, Krajcik, & Borko, 1999, p 99)

A short presentation of the components a–e follows. Magnusson et. al. (1999) describe them in this way:

(a) ‘Orientations’ as teachers’ knowledge and beliefs about both the purposes and goals of teaching science at a particular grade level. These orientations work as a ‘conceptual map’, guiding teachers’ instructions, while influencing and being influenced by the other components b–e.

(b) ‘Curriculum’ as teachers’ knowledge of the goals and objectives for pupils in the subject(s) they are teaching. This includes articulation of guidelines across topics addressed during a school year and development of topics during the different school years. This builds on e.g. national or state guidelines for science, as well as specific curricular programs and material.

(c) ‘Pupils’ understanding’ as knowledge that teachers need in order to help pupils develop specific scientific knowledge. This includes knowledge about requirements pupils have for learning specific concepts, their approach to understanding them, skills they might need, and different developmental, ability or learning styles pupils might have.

(d) ‘Instructional strategies’ as knowledge about general approaches to or overall schemes for enacting science instruction and knowledge of topic-specific strategies that are useful for helping pupils comprehend specific science concepts. This includes knowledge about topic-specific representations, their weaknesses and strengths, and the ability to invent representations that help pupils to develop an understanding of specific concepts or relationships. It also includes knowledge about activities that can be used to help pupils comprehend specific concepts or relationships, their conceptual power, and the extent to which the activity presents, signals or clarifies important information about a specific concept or relationship.

(e) ‘Assessment’ as knowledge of the dimensions of science learning that are important to assess as directed towards a particular unit of study. This includes knowledge about specific methods, instruments, procedures, approaches or activities. It also includes knowledge about the advantages and disadvantages associated with employing a particular assessment device or technique. Thus, knowing about a number of ways to assess enables the teacher to choose the most appropriate way to assess desired learning (Magnusson et al., 1999).

Magnusson et al.'s framing of PCK, as presented above, signals two important ideas concerning the development of becoming a expert teacher. The first is that teachers need to develop knowledge within all of the aspects of PCK. The second is that teachers need to develop knowledge with respect to all of the topics that they teach. One important consequence of this is that if a teacher only develops knowledge within one component, or does not develop the connection between components, then he/she might not develop their PCK for science. Furthermore, since PCK knowledge is topic-specific, the implication is that PCK knowledge is not directly transferable to other topics (Magnusson et al., 1999).

2.3.4 The ecology of PCK development

The previous sub-section focused on describing a subject-specific model of PCK and how it theoretically relates to three knowledge domains. The present sub-section aims to provide some empirical evidence for these relations. In this regard, it is important to note that this empirical evidence is directly connected to the fragmentation problems outlined in section 2.1 and with stances and research discussed in sub-section 2.2.2.

When studying PCK development, researchers have generally found positive correlations between pedagogical knowledge and PCK (Kind, 2009). For instance, Geddis, Onslow, Beynon and Oesch (1993), in their study of chemistry teachers, found that teachers who adopt a 'transmission' model of teaching, fail in making pupils understand descriptions and explanations. On realizing this, the teachers consequently changed their pedagogical knowledge. Likewise, Henze, Van Driel, and Verloop (2007) found that teachers focusing on behaviourist/cognitive ideas, used instructional strategies that were primarily focused on science content. In contrast, teachers with a more constructivist pedagogical knowledge taught in a more integrated manner that included knowledge of pupils' learning and a set of diverse learning objectives. Simmons, Emory, Carter, Coker, Finnegan et al. (1999) underlined the difference between having pedagogical knowledge and actually implementing it. In their study from nine universities, they found that about 40% of teachers during their first year of teaching thought that they taught from a pupil-centred perspective, taking pupils’ prior knowledge and misconceptions into account, while they in fact had adopted a transmissive mode of teaching.

Many studies have also shown that SMK development is correlated with PCK (Van Driel et al., 2014), although the connection is not always straightforward (Kind & Kind, 2011; Nehm, Kim, & Sheppard, 2009). For instance, Johnston and Ahtee (2006) found that unless PSTs had developed a sound SMK, PCK development was bound to be minimal. Likewise, Sperandeo-Mineo, Fazio and Tarantion (2006) found that gains in SMK helped PSTs to construct PCK. An example of why this is the case is given by Käplyä, Heikkinen, and Ausuta (2009), who describe teachers with low SMK as having problems in understanding pupils’ conceptual difficulties and problems in choosing important content. Furthermore, low levels of SMK have also been connected to using passive teaching strategies, while higher SMK is associated with more confidence in teaching and the use of interactive and adventurous approaches (Van Driel et al., 2014). Furthermore, Kaya (2009) shows that there is a medium to strong correlation (from 0.32 to 0.77) between SMK and the different PCK components. Yet, surprisingly, the assessment component was not correlated with the other PCK components. Finally, Davis (2004) found that even if teachers expressed good SMK, their instructions could nevertheless be flawed. Therefore, good SMK, it is not an automatic precursor for good PCK.

Some studies have also looked into the link between pedagogical knowledge, SMK and PCK. These studies have not surprisingly shown that poor pedagogical knowledge and SMK generally hinder PCK development (Usak, Ozden, & Eilks, 2011). However, pedagogical knowledge and SMK also seem to influence each other. In this regard, Kaya (2009) found that high SMK leads to more appropriate use of pedagogical knowledge, whereas low SMK leads to the use of more naïve pedagogical knowledge.

Few studies have singled out the influence of context on PCK development. However, Rollnick et al. (2008) found that teachers with similar SMK manifest their PCK quite differently when placed in various contexts. Cohen and Yarden (2009) found in addition that contextual factors, such curricular changes imposed from the educational system, could be an important factor in PCK development. They also found that PCK development is dependent on the knowledge shared amongst colleagues.

2.3.5 A possible new way forward – critique of the old model

In 2012, after the present study had collected and analysed the data, it became apparent that the field of PCK research had become too fragmented, which had led to limited use of PCK both theoretically and in the field. Therefore, 24 researchers from seven countries worked together to create a common terminology and definitions based on their common research, resulting in the development of a consensus model for science PCK called 'Teacher Professional Knowledge & Skill including PCK and influences on classroom practice and pupil outcomes'(TPK&S), as presented in Figure 5 (Gess-Newsome, 2015). Overall, the consensus model addresses many of the shortcomings identified by researchers within the field, e.g. whether PCK is integrative or transformative. Therefore, this new model needs to be considered when discussing PCK development in this extended abstract, even if this study is based on an older model. This is the reason why the coming sub-section will initially focus on describing the new model, and then discuss how the new model relates to Magnusson et. al.s' (1999) model.

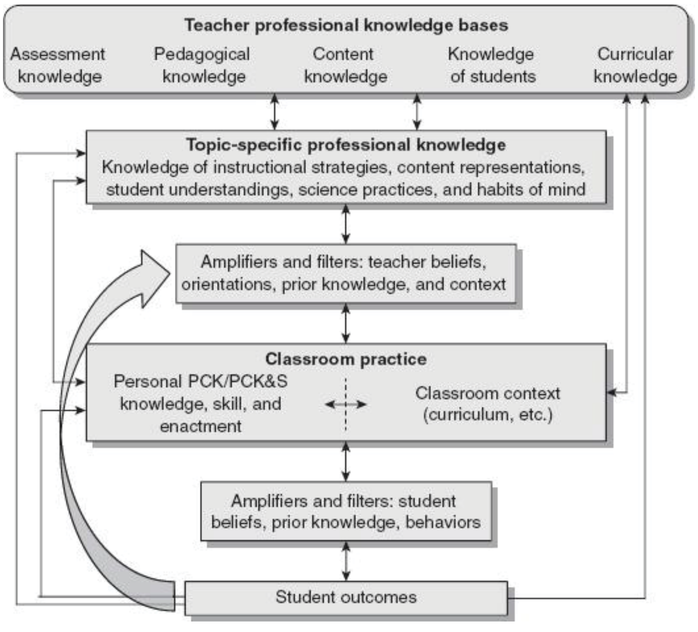

Figure 5: Consensus model of Teacher Professional Knowledge & Skill including PCK and influences on classroom practice and student outcomes (TPK&S) (Gess-Newsome, 2015, p. 86)

Gess-Newsome (2015) describes the consensus model as follows. The model of TPK&S originates in the generic 'Teachers professional knowledge bases (TPKB)', shown at the top of the figure. This category represents generalized professional knowledge, which builds on results from research and best practices, and is aligned with knowledge bases presented by Shulman (1986). It can therefore be codified and taught. While the TPKB is generic, its power lies in its application to the teaching of a specific topic. The generic knowledge from TPKB both informs and is informed by topic-specific professional knowledge (TSPK). The TSPK category represents a blend of knowledge of subject-matter, pedagogy and context. Knowledge within this category is directed at making effective instructional decisions. Both TPKB and TSPK are thought to be context-free, as opposed to the rest of the model.

The knowledge from TPKB and TSPK is then influenced by affective factors, which act as amplifiers or filters that mediate a teacher's actions in the classroom. This is followed by the PCK category and a new category, 'Pedagogical Content Knowledge and Skill' (PCK&S). While PCK is defined as:

> "*The knowledge of, reasoning behind, and planning for teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes (Reflection on Action, Explicit)*".

PCK&S is defined as:

> "*The act of teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes (Reflection in Action, Tacit or Explicit)* (Gess-Newsome, 2015, p. 98)".

At the bottom of the model, student or pupil outcomes and their connection to the other components are made explicit. From the presented connections, it follows that learning does not directly follow from instruction, since students also have amplifiers and filters. Furthermore, since the components are considered recursive and dynamic by nature, both student outcomes and classroom practices have the possibility to further inform TSPK and TPKB. In this way, feedback loops are created which underscore the complexity of how teaching and learning occur.

The TSPK&S model has addressed several weaknesses that have not been resolved in the Magnusson et al. model. First, the TSPK&S model distinguishes PCK from TSPK. By doing so, the tension leading to either a transformative or integrative view of PCK has been removed (Gess-Newsome, 2015) (See discussion in 2.3.2.). Second, TSPK&S addresses the complex issue of how PCK develops (Gess-Newsome, 2015). This is accomplished by explaining the connection and dynamics between the knowledge bases, the topic-specific knowledge, classroom practice and student outcomes, and how these are further influenced by a teacher and his/her students' filters. Thirdly, TSPK&S addresses social and socio-cultural learning issues (Gess-Newsome, 2015). It does so by distinguishing between the personally held PCK knowledge and the ability to put this knowledge into action (PCK&S), and further by placing the development of this into a specific context that directly influences PCK and PCK&S. Fourthly, it addresses the relationship between orientations and the effect of orientations on PCK by placing these as a filter, and thereby distinguishing them from PCK (Gess-Newsome, 2015).

It naturally follows from this that the model developed by Magnusson et al. (1999) and the TSPK&S model are not totally compatible. However, from the descriptions provided above, I will argue that the fundamental distinctions made in both models are similar. For instance, both models have a clear generic knowledge base placed outside the realm of PCK/&S. Both models also include the context. However, in the TSPK&S model, the context is directly linked to PCK/&S, whereas in the Magnusson et al. model, it is considered a knowledge base. Both models also describe topic-specific knowledge and that orientation/beliefs influence this knowledge when developing PCK/&S. In the Magnusson et al. model, however, the ways the topic- specific components and orientations/beliefs influence PCK development are less specific than in the TPK&S model. Finally, while the Magnusson et al. model mainly focuses on cognitive knowledge, the TPK&S model specifically distinguishes between PCK as knowledge on action and PCK&S as knowledge in action. The latter difference is, however, smaller when the Magnusson et al. model is combined with Shulman's model of pedagogical reasoning and action, since the latter model considers both the process of knowledge on action and in action.

As shown, the consensus model thus brings together many years of research and perspectives into one coherent and complex model of PCK/PCK&S and its development. This is done in a manner that aligns with the theoretical underpinning discussed in section 2.2. Furthermore, the model indicates that educational programs aiming at developing teachers' PCK should be aligned with teachers' professional practice, thereby corresponding to aspects highlighted in section 2.1. For these reasons, the extended perspectives on PCK and its development will be used to broaden the perspectives presented during the discussion chapter, even though the analysis is based on the Magnusson et al. model.

In light of the presented PCK framework, the following section will look into how educational sites can promote PSTs' PCK development. This will be done by looking into how teacher education can be aligned with PCK research that indicates that educational programs should provide teachers with specific input, including opportunities to enact certain instructional strategies and to reflect on their experiences, both individually and collectively (Van Driel & Berry, 2012), as outlined in section 2.1.

2.4 Development of PCK

This section will use previously presented theory (sections 2.1–2.3) to argue why the Lesson Study (LS) method and the Content Representation (CoRe) tool are possibly two means that could develop teachers' PCK in science during field practice placement. It will also argue why a combination of both is needed in this context. When reading the presented arguments, it is important to keep in mind the dynamic and recursive relationship between the PCK components ('Knowledge of curricula', 'Knowledge of pupils' understanding', 'Knowledge of instructional strategies' and 'Knowledge of assessment') and between PCK and the different knowledge bases ('Context knowledge', 'SMK' and 'Pedagogical knowledge'), as argued through sub-sections 2.3.3 and 2.3.4. One needs to keep this in mind since increased knowledge within the PCK components, of the knowledge bases or of their connections, can potentially spur PCK development. The same can be argued about the dynamic and recursive relationship between TPKB and TSPK in the consensus model, that through amplifiers and filters influence teachers' PCK/PCK&S development, as described through sub-section 2.3.5.

2.4.1 Developing PCK through Lesson Study

In this sub-section, I will show how LS incorporates many of the important features that have been identified within the teacher education field presented in section 2.1, by the learning theories presented in section 2.2, and by the PCK research presented in section 2.3. The aim is to show why LS has been found to develop PSTs' PCK (e.g. Pongsanon et al., 2011; Weiland et al., 2010), which may be the reason why LS research indicates that the method improves pupils' learning (Lewis & Perry, 2014; e.g. Lewis et al., 2009; Lewis, Perry, Hurd, & O'Connell, 2006; Perry & Lewis, 2009; Saunders, Goldenberg, & Gallimore, 2009; Waterman, 2011). This examination is necessary since efforts to build a theoretical model of LS, or to document the features and impact of LS, have been modest to date (Lewis et al., 2009). Therefore, this sub-section first presents evidence as to why LS, as researched both within schools and teacher education, is considered to build PCK. The term 'teachers' in this part is thus used generically. It then presents key steps in the LS process connected to the building of PCK. Finally, these features will be discussed in the light of the presented theory.

Lewis and Hurd (2011) argue that LS builds on sustained professional knowledge within schools and across professions, arguments also echoed by European researchers (e.g. Dudley, 2014; Munthe, Helgevold, & Bjuland, 2015). Their reasoning is that LS values teaching, teachers and the professional community, and cultivates all of these in order to bring about sustained instructional improvement through knowledge development. It does so by assuming that teachers need opportunities to work together with colleagues during practice and also that teachers need to carefully study pupils' thought processes, and how these relate to instruction. It also assumes that teachers need to be able to revisit this thinking based on different instructional forms. Furthermore, it needs to build on the teachers' own interests in order to motivate them to continue improving their own teaching and that of their colleagues. The product is thus the creation of a shared knowledge base for teaching, which happens through the publication of lived research lessons, written reports, videos and networking with colleagues. Murata (2011) further argues that the LS process makes research more practical, understandable, and it gives teachers the opportunity to develop a deeper knowledge of content, pupils' thinking, and the connection between the two.

The aforementioned effects of LS are closely linked to the development of PCK as described in section 2.3, and closely resemble the definition of PCK provided in sub-section 2.3.1. This is the case since a combination of what is presented above shows that the LS method seeks to improve instruction through a group effort, which allows the participants to deeply focus on, discuss and combine their knowledge of pedagogy and SMK, and how this can be implemented into practice to teach a specific set of pupils in the best possible manner. It is through these effective ways of thinking that theory is connected with practice (Murata, 2011) and that LS has been found to increase teachers' opportunities to develop their PCK (e.g. C. Fernandez, 2005).

The arguments presented above are echoed in the majority of international and European research that finds that LS and variants of it, such as learning studies, benefit professional development within three main areas: 'Teacher collaboration and development of professional learning community', 'Development of professional knowledge' and 'More explicit focus on the pupils' learning' (Xu & Pedder, 2014). These areas correspond to both the cognitive and the social/socio-cultural learning theories described in section 2.2.

The professional learning communities are found to be developed as a consequence of an increase in teachers' collegiality, joint decision-making, and joint responsibility and ownership of teaching (Andrew, 2011; Cohan & Honigsfeld, 2007; Gunnarsdóttir & Pálsdóttir, 2016; Hope & Grimsæth, 2016; Hunter & Back, 2011; Lawrence & Chong, 2010; Parks, 2008; Sims & Walsh, 2009). During this process, teachers benefit from the mutual sharing of knowledge and resources about teaching and learning (Davies & Dunnill, 2008; Dudley, 2013; Lewis et al., 2009; Pang, 2006; Sibbald, 2009); from their in-depth discussions about classroom issues (Jørgensen, Rostgaard, & Mogensen, 2016; Roback, Legler, & Moore, 2006; Rock & Wilson, 2005); from teaching while being observed and observing others teach, and by giving and receiving feedback (Gu & Wang, 2006; Rock & Wilson, 2005; Yang, 2009); and by sharing different perspectives on teaching for successful learning (Roback et al., 2006; Sibbald, 2009). Consequently, collaboration seems to increase the profoundness of the discussions that occurs, compared to that of normal practice (e.g. Helgevold et al., 2015; Sundli, 2007).

Researchers also report on increased teacher knowledge, practice and professionalism (Dudley, 2013; Hedegaard, Krog, & Høy, 2016; Helgevold, Næsheim-Bjørkvik, & Østrem, 2016; Marble, 2007; Rock & Wilson, 2005). Specifically, gains are reported in teachers' SMK, pedagogical knowledge and knowledge about pupils (Dudley, 2011, 2013; C. Fernandez, 2005; Kullberg, 2016; Lewis, 2009; Marble, 2007; Skott & Møller, 2016). Therefore, it is not surprising that PCK development is reported (Dudley, 2011, 2013; C. Fernandez, 2005; Lewis, 2009; Lewis et al., 2009; Sibbald, 2009), since these aspects play a crucial role in PCK development (see section 2.3). This happens partly as a consequence of becoming more critically reflective about one's own practice (Andrew, 2011; C. Fernandez, 2005; Larssen & Drew, 2016; Ricks, 2011). Critical reflections are partly a consequence of teachers daring to experiment with new teaching ideas and pushing themselves further than normal (Hope & Grimsæth, 2016; Norwich & Ylonen, 2013; Rock & Wilson, 2005; Sibbald, 2009). These changes have been found to be especially helpful in changing orientations and beliefs about teaching (Pella, 2011; Sibbald, 2009), a major challenge in learning how to teach (see sub-section 2.1.1).

LS has also been found to change teachers' frame of mind from focusing on their own teaching to pupils' learning (Gunnarsdóttir & Pálsdóttir, 2016; Norwich & Ylonen, 2013; Pang, 2006; Perry & Lewis, 2009; Skott & Møller, 2016). In this process, teachers have been found to become more aware of and responsive to their pupils' prior knowledge (Dotger, 2011; Kullberg, 2016; J. F. K. Lee, 2008). They have also been found to focus on learning goals in light of what their pupils already know (Holmqvist, 2010; Holmqvist, Brante, & Tullgren, 2012; Sims & Walsh, 2009), and to become better at anticipating learning difficulties and creating strategies that address these difficulties (Baduk, 2012; Hart, 2009; Skott & Møller, 2016; Yang, 2009). In sum, this creates more favourable conditions for pupils and their learning (M. Fernandez, 2010; J. F. K. Lee, 2008; Marble, 2006), and supports PCK development since a focus on pupils and their learning is an important aspect of developing PCK, see section 2.3.

All of the above changes happen through the LS cycle. This is the reason why it is necessary to understand its key features. Figure 6: 'Key features of Lesson Study', shows the most important content of each of the LS cycle steps. This figure builds on the explanation given by C. Fernández and Yoshida (2004). It is important to know that teachers work together as a group during the LS cycle, bearing equal responsibility for the development, conducting and reflection on a research lesson, a process spread out over several meetings and lasting up to several months (Lewis & Hurd, 2011). The use of 'research lesson' in this respect implies that the main aim of the teaching of the lesson is for the group to gather information about their main research question and predictions made about pupils' learning, and not, as commonly misunderstood, to determine the lesson's effectiveness (Cerbin & Kopp, 2006).

Key features of LS

1. Planning of the research lesson:
    a. Research goal
        i. Design a research question aimed at solving a specific teaching problem that encapsulates what to learn more about
        ii. Determine goal for pupils' learning
    b. Investigation
        i. Considering pupils' current characteristics
        ii. Consider long term goals for pupils' learning and development
        iii. Study the content area: Key concepts, existing curricula, standards, learning trajectory and prior research within the research area
        iv. Find ways to make pupils' learning visible in the classroom
    c. Planning
        i. Detailed group planning of a research lesson: Predict response and consequences for pupils' learning.
        ii. Development of assessment material to collect evidence about pupils' learning: Key focus on individuals, groups or through process.
2. Conducting the research lesson
    a. One is chosen to teach the lesson: One has to adhere to the lesson plan.
    b. Team members gather assessment evidence that is directly connected to the chosen way of teaching to shed light on the posed research question.
3. Reflection after having taught the research lesson
    a. Sharing and discussion of evidence collected from the research lesson
    b. Drawing out implications for lesson redesign, for teaching and learning more broadly, and for understanding of pupils and subject-matter.
    c. Summarize findings
4. Revise and re-teach the lesson (optional number of times)
    a. Use summarized findings to revise the lesson plan
    b. New predictions for pupils' responses and learning are made
    c. Another teacher teaches the revised lesson to a new but similar class

5. Disseminate findings
    a. Summarize findings from both research lessons
    b. Disseminate through live research lessons, written reports, videos

Figure 6: Key features of Lesson Study. Based on C. Fernández and Yoshida (2004)

On the basis of the steps in the LS cycle, Lewis, Perry and Hurd (2009) argue that LS develops knowledge that resonates with both cognitive, social and social cultural theories. They argue that LS, by making various types of knowledge more visible, such as colleagues' ideas about pedagogy and pupils' thinking of subject-matter, thereby enables teachers to encounter new or different ideas and to refine their knowledge. They also argue that LS enables teachers to strengthen the professional community, the building of norms for inquiry, accountability, shared language, and a framework for analysis of practice. LS also enables them to develop tools needed for instructional improvement that are shared through teaching and learning resources. In this way, the LS method seems to develop and considers both cognitive, social and socio-cultural learning theoretical perspectives as mechanisms for learning, as described in section 2.2. In turn, these mechanisms might lead to a more coherent understanding and shared vision of teaching, which is incorporated into powerful educational programs (see section 2.1.2).

On the basis of the descriptions of the consensus model of TPK&S (see Figure 5, p. 37), the following will argue for how the steps of the LS cycle may add to the understanding and development of PCK. From the LS key focus points presented above, it can be seen that the LS process focuses the group's attention on all of the described knowledge bases and topic-specific knowledge for professional teaching (TPKB + TSPK), contrary to that of regular practice (e.g. Sundli, 2007). These are: 'Assessment knowledge', 'Pedagogical knowledge', 'Content knowledge', 'Knowledge of pupils' and 'Curricular knowledge' together with 'Knowledge of instructional strategies', 'Content representations', 'Pupil's understandings', 'Science practices' and 'Habits of mind'. This happens within a specific context (one field practice school, one mentor, one classroom, and among one group of learners). Furthermore, the teaching is carried out within a specific subject (physics), while focusing on the teaching of a specific topic. This means that when LS challenges teachers to consider TPKB and TSPK in a specific context, subject and topic, it challenges the PSTs to voice their own PCK or show their PCK&S, as filtered through their beliefs, orientations, prior knowledge, and the context. This is achieved through careful consideration and discussion as a group. In this way, the LS process provides researchers with the possibility to glimpse how teachers manifest PCK and PCK&S. Furthermore, as described, it has the possibility to develop teachers' PCK and PCK&S through an increased reflective focus on TPKB, TSPK, their connection, and how this is used to improve instruction.

2.4.2 A critical view on the impact of LS on teachers' PCK development

Even though the prior sub-section describes why research appears to find that LS seems to have a positive influence on teachers' development of PCK, it is nevertheless important to keep a critical lens. This becomes especially apparent since several researchers have identified reasons as to why teachers within the USA/European context seem to have difficulties in engaging with LS in a profound way (Doig, Groves, & Fujii, 2011; Murata, 2011; Yoshida & Jackson, 2011). The present sub-section will discuss the engagement problem in light of the presented theory in order to identify a possible means that might address this problem.

In Japan, teachers' learning of the LS method already starts during teacher education. Here PSTs enter into the LS culture through collaboration with experienced university mentors, field practice mentors, and outside experts when practising LS (C. Fernandez & Yoshida, 2004). During this process, they experience substantial numbers of developed research lessons, from which they can seek out knowledge, as well as try out model lessons. Furthermore, they also observe an average of ten research lessons per year (Elipane, 2012). In this way, working together with experienced teachers naturally helps the PSTs to understand and gain a deep understanding of the LS process (C. Fernandez & Yoshida, 2004). In doing so, enculturation becomes an important aspect of acquiring this deep conceptual knowledge of the LS process, so that these teachers can conduct it efficiently. Although this might seem easy on the surface, experience shows that this process takes a good deal of effort and dedication (Chokshi & Fernandez, 2004; Yoshida, 2008).

Outside of the Japanese setting, however, these mechanisms of enculturation and teaching materials do not exist to a great extent. This is one reason why Yoshida and Jackson (2011) argue that many non-Japanese teachers conducting LS only attend to its surface features, while failing to engage in a way that sufficiently impacts their PCK. It is especially the process of *kyozaikenkyu* (the planning stage of the LS) that is an area where newcomers struggle to engage sufficiently (Doig et al., 2011; Fujii, 2016). This problem is exacerbated by the fact that a strong knowledge base is needed to support good planning, observation, and discussion (Doig et al., 2011), something that PSTs naturally still have to develop. Murata (2011) and C. Fernandez, Cannon, & Chokshi (2003) additionally find that teachers struggle to maintain a research focus through the LS process. Consequently, teachers, especially those new to LS, fail to understand LS as complete complex experience – as stories with a connected beginning, middle, and end, where meaning is found in the connections between the parts. Therefore, they only gain superficial knowledge, which means that they are missing out on the main point (Stigler & Hiebert, 1999). For this reason, it is suggested that newcomers to LS need a scaffolding tool grounded in strong content and pedagogical knowledge that can help them to engage effectively with this profound and difficult method, especially during the planning part (Amador & Weiland, 2015; Lewis & Perry, 2014; Yoshida & Jackson, 2011). The next sub-section will argue why CoRe might represent such a tool.

2.4.3 Content Representation: Scaffolding the LS process and developing PCK

As argued above, LS needs a scaffolding tool which is grounded in both strong content and pedagogical knowledge as a means to help newcomers engage sufficiently with the planning process. Furthermore, it would be beneficial if this tool also supported the development of PCK within the subject of science. In the following, I will argue that the CoRe tool is a candidate for this objective, since it fulfils all of the above criteria.

Originally, the CoRe tool was developed with two aims in mind: first, as a means to develop teachers' PCK within science, and second, as a means to portray teachers' science PCK (Loughran et al., 2012). The tool has thus currently been used successfully as both a research and development tool for science teachers' PCK (Cooper et al., 2015). This success may have been obtained through the development of a form, shown in Figure 7: ‘Content Representation (CoRe) form’, which combines and relates content aims with the pedagogical knowledge required to teach in the classroom, which is a crucial part of developing PCK (see section 2.3).

Content: Age of children:	Big Idea A	Big Idea B
What do you intend students to learn about this idea?		
Why is it important for students to know this?		
What else might you know about this idea that you don’t intend students to know yet?		
What difficulties or limitations are connected with teaching this idea?		
What do you know about student thinking about this idea?		
What other factors influence your teaching of this idea?		
What instructional strategies will you use and why?		
How will you monitor student understanding or confusion around this idea?		

Figure 7: Content Representation (CoRe) form (Loughran et al., 2012, pp. 22–23).

As seen above, the CoRe form challenges the teachers’ thinking about teaching a specific science topic to a specific class, based on the recognition of the ‘big ideas’ for that topic (Row 1). ‘Big ideas’ are to be understood as those that a teacher considers as being at the heart of understanding a specific science topic for a particular class under consideration. This means that the word ‘big’ can be misleading, since ‘big’ refers to the importance of the idea. However, the idea itself represents the smallest unit of a specific learning aim. The developed ‘big ideas’ are then mapped against eight pedagogical prompts that need to be considered in relation to each ‘big idea’ (Column 1, Rows 2 to 9). Based on the descriptions from the pedagogical prompts, the ‘big ideas’ are then sequenced and placed in a logical order. In this way, the ‘big ideas’ focus attention on the role of the content in a new and different way; it is no longer about content knowledge as information, but about conceptual understanding of the content for teaching. Many of the prompts support this by requiring consideration not only of how it might be taught, but also of how it might (or might not) be learned. Teachers are then challenged to think differently about what they are doing, how, and why, when teaching a specific science topic, instead of thinking of teaching as simple delivery of content knowledge (Loughran et al., 2012). For the reasons explained above, Kind (2009) argues that the CoRe is the most useful technique devised to date for eliciting and recording PCK directly for teachers.

Loughran, Berry and Mulhall (2012) argue that the main way in which the CoRe helps teachers to improve their PCK is through the direction of reflections, as described above. This conclusion is supported by both international and European research on the use of CoRe.

For instance, Loughran et al. (2004) found that the process of reflecting on and filling in a CoRe form was professionally rewarding since it required teachers' tacit knowledge of science teaching and learning to become much more explicit, which is normally found to be challenging to accomplish (Edwards, 1997a; Gess-Newsome, 1999; Korthagen & Kessels, 1999; Loughran et al., 2000). In a later study, Loughran, Mulhall, and Berry (2008) invited PSTs to construct their own examples of CoRes for different topics after they had examined and reflected on those created by expert teachers. They found increased links between science content and pedagogy, which they argue indicates a more sophisticated view about learning to teach science, and how to teach for understanding, both of which indicate development of PCK (see section 2.3). Additionally, Berry, Loughran, Smith and Lindsay (2009) found that working with a CoRe seems to create a particular professional language, which is often missing. Later, Bertram and Loughran (2014) showed that the CoRe could make PSTs shift from a transmissive approach to teaching to approaches that were more pedagogically reasoned, which would arguably support PCK development as described in section 2.3.

Other researchers, such as Lehane, O'Reilly, and Mooney-Simmie (2013), found that collaborative workshops around filling in a CoRe created professional learning communities in which PSTs could share their ideas, work together, and consider how they would teach a variety of topics. The developed ideas were further found to be successfully implemented into classroom practice. The creation of learning communities was also in focus when Donelly and Boniface (2013) used online collaboration to fill in CoRes to break with in-service teacher isolation. They likewise reported that teachers appreciated reflecting on and sharing their professional practice in a community of learning. In this way, the CoRe, arguably in the same way as LS, supports the collaborative efforts to gain deeper knowledge about aspects of PCK than what could be expected to be developed individually. Chordnork and Yuenyong (2014) used the CoRe with elementary school teachers to facilitate them in developing a greater understanding of teaching global warming. Their study suggests that the CoRe offered a means for the teachers to understand the construct of PCK and its influence on science teaching. In similar veins, Nilsson and Loughran (2012b) used the CoRe in planning for and assessing PSTs' own learning related to teaching elementary school science. The findings indicate that the CoRe acted as a trigger that encouraged PSTs to begin to embrace the notion of PCK in their own practice. In a later study, Nilsson (2013) used the CoRe to look into PSTs' approaches to teaching a science topic and the reasons behind that approach. The results indicate that the use of CoRes, together with subsequent self-assessment and formative interactions with teacher educators and peers, can potentially lead to PCK development.

Working with the CoRe has also been reported as a challenging endeavour. For instance, Hume and Berry (2011) reported that PSTs found the process of filling in a CoRe challenging due to their lack of classroom experience. Therefore, they argue that the CoRe needs to be properly scaffolded in order to develop PCK. Research by e.g. Davidowitz and Rollnick (2011) indicates that such scaffolding could come from expert teachers and their filled in CoRes. Williams et al. (2012) and Williams and Lockley (2012) looked into such scaffolding by investigating PSTs' co-construction of CoRes together with expert teachers. Through their investigations, they found that the use of CoRe helped novice teachers to develop deep knowledge about the content, confidence in what they were teaching, and confidence to explore new pedagogical strategies. Similar findings were reported by Eames et al. (2011), who further argue that working with the CoRe in this manner helped to develop PCK. Other uses for the CoRe include science curriculum development (Park Rogers et al., 2012) and measurement of PSTs' PCK change over time (Adadan & Oner, 2014).

On the basis of the first key LS feature (shown in Figure 6, p. 44-45), which describes the content of the planning step, I will argue that through filling in the CoRe form, teachers will have to consider these aspects in greater detail than is the case for most non-Japanese teachers. In turn, this might also influence the consecutive LS steps.

First of all, the CoRe's pedagogical prompts explicitly direct the teachers' attention towards the main areas described in the LS planning process, while also making them formulate and explicitly state these understandings. For instance, it directs special awareness to the learner and how the way of teaching and choices made for materials might influence the way that the learner learns (Nilsson & Loughran, 2012b). It also focuses on the collection of evidence in order to make evidence-based assessment (Loughran et al., 2008). The CoRe further provides an interconnected structure that leads teachers to consider how the different pedagogical prompts influence each other, which in turn increases the pedagogical purposefulness of their choices (Cerbin & Kopp, 2006). The structure may thus scaffold the difficult process of voicing tacitly-held knowledge (Loughran et al., 2012), so that teachers can discuss in groups, refine and develop these ideas, as suggested by social and socio-cultural theory (see section 2.2). Furthermore, the explicit structure may scaffold the process of developing understanding, as suggested by cognitive constructivist theory (section 2.2).

In these ways, the CoRe provides an interconnected structure that guides reflections by directing focus to both pedagogical knowledge, content knowledge, and their relation to practice (Mulhall, Berry, & Loughran, 2003; Nilsson & Loughran, 2012a), thus in turn supporting PCK development. Most of these aspects are somewhat salient features of the LS process, which may be why teachers outside the Japanese context do not engage with them in a sufficient manner (Doig et al., 2011; Yoshida & Jackson, 2011). Filling in the CoRe form may thus specifically add to teachers' PCK by making salient LS features explicit and by connecting these into a coherent whole.

3 The research process

The previous chapter has used a learning theoretical perspective to outline the rationale for choosing to use LS in combination with CoRe during teacher education field practice in science in order to address the problem of combining theory and practice. This chapter is concerned with the practical approach to how this was carried out and why it was chosen to be carried out in that specific manner. This is done through a description and discussion of the overarching research design and a description and discussion of the specific research conditions, data collection, and participants. Finally, considerations about issues of quality and ethics are examined in light of these decisions.

3.1 Overarching research design

The purpose of this section is to show how the project TasS and its aims, together with the theoretical understanding presented, was used to develop an overarching research design which, through four articles, would collect evidence about the use of LS combined with CoRe during field practice in order to address the problem of combining theory and practice. To do so, an understanding of the project TasS is necessary, of which this study is a part. In subsequent light of this, a theoretical framework for examining the problem, relying on prior theory, will be discussed. Finally, the main research question is presented, together with the sub-research questions used in each of the four articles.

3.1.1 The framework of the TasS project

The specific research presented here was conducted as part of a larger cross-disciplinary research project entitled Teachers as Students (TasS, 2012–2015), which was supported by the Norwegian Research Council, grant number 212276. A thorough description of the TasS project's aims and methods has recently been described by Munthe, Bjuland and Helgevold (2016).

Munthe et al. (2016) describe TasS as interested in finding out how Norwegian teacher education can develop both PSTs and teacher educators who are able to study and learn from the consequences of teaching. The TasS project thereby aimed to study what teacher education could do to bring about this change, to shift the focus from the teacher to relationships between teachers, teaching, and pupils' learning. TasS specifically argued that one way of addressing this challenge would be to implement and use LS as an approach during PST field practice.

Therefore, the TasS research group decided to conduct a time-lagged experiment (Hartas, 2010) at one specific Norwegian teacher education. The experiment included two conditions: A current state of practice (CSP) condition (control group) year 2012, and an intervention (INT) using the LS approach, year 2013. This meant that participants would differ between the two years of the data collection. However, a time-lagged experiment, as opposed to traditional experiments and quasi-experiments, allows calibration of the intervention and it allows the possibility of tracing the evolution of learning in complex, messy classrooms and schools (Brown, 1992). Furthermore, a time-lagged design, which starts with the control group and introduces the intervention the year after, ensures that the intervention does not rub off on the participants from the control group, thus avoiding 'contamination' of the data (Hartas, 2010).

The TasS study covered the subjects English as a second language, Physical Education, Mathematics and Science, with researchers from each subject joining the research project. Furthermore, researchers who studied multicultural perspectives, and general pedagogical perspectives, also participated. The TasS project thus provided researchers with the possibility to work cross-disciplinary, which was done in addition to the pure subject-specific studies (Munthe et al., 2016). Consequently, the main research questions for the TasS project were approached from many different views, which is a methodological strength. One effect is that the design does not allow for a control of how the specific context, researchers, mentoring teachers or PSTs, influence the results.

The TasS group decided to collect data for both the CSP and INT through video recordings of the steps depicted in Table 1: Data collection for TasS.

Table 1: Data collection for TasS

	What was done
Step 1.	Pre-focus group interview with the PSTs.
Step 2.	Pre-mentoring with mentor and PSTs.
Step 3.	Research lesson taught by PSTs.
Step 4.	Middle mentoring with mentor and PSTs. (Split into post- and pre-mentor during CSP)
Step 5.	Research lesson taught by PSTs. (CSP new lesson/INT revised lesson).
Step 6.	Post-mentoring with mentor and PSTs.
Step 7.	Post-focus group interview with PSTs.

The decision to include pre- and post-interviews, steps 1 and 7, was based on the need to be able to compare these two stages, as well as getting an idea of differences and similarities within the groups. Furthermore, these interviews were used to focus on broader thematic implications. The decision to have two consecutive planning, teaching and reflection cycles, steps 2–4 and 4–6, was dependent on the LS model. Doing so would allow the researchers to follow the whole LS process (Munthe et al., 2016).

All of the above decisions made by TasS had implications for how I chose to approach the main research question of the present study, as will be explained in the following sub-section.

3.1.2 Approaching the main research question through four Articles and their research questions

As described above, the TasS project provided the main aims for the research, the main method of intervention, and the main design for the collection of data. Within this context, and during the TasS research period, I have conducted research that has exclusively studied physics as a sub-set of science since I am a science researcher. In addition to the use of LS, this specific project has added the CoRe as a scaffolding tool during the INT condition. The reasons for this are explained in section 2.4.

For the reasons explained in Chapters 1 and 2, this study aims to answer the main research question.

> *"How does the use of Lesson Study combined with Content Representation affect pre-service science teachers' potential to start developing Pedagogical Content Knowledge during field practice in teacher education?"*

To approach this main research question, I relied on Shulman's 'Model of pedagogical reasoning and action' (1987), as presented in Figure 2, p. 28, in which Shulman theorizes about and describes the process through which PCK develops. From this, it becomes evident that in order to say something about the collective development of PST groups PCK, all six of the processes ('Comprehension', 'Transformation', 'Instruction', 'Evaluation', 'Reflection' and 'New Comprehension'), would need to be studied and synthesized together in order to answer the research question.

Furthermore, as explained in section 2.4, only a few studies have tried to build a theoretical framework of how LS impacts the knowledge required by teachers to become experts (Lewis et al., 2009). Therefore, it would be a strength, compared to other studies, if the present study could reach such an understanding. One way of doing this would be to use PCK as a theoretical standpoint when comparing the CSP and the INT. However, as argued in Chapter 1, there is also a need for holistic research that examines the whole process of planning, conducting and reflection on teaching a specific lesson. Such research would need to show the reasons for acting in this specific manner from a PCK perspective.

This means that two different methods of analysis are required, each of which on their own would not necessarily cover the whole process of pedagogical reasoning and action. However, when combined, they would attempt to do so. Since little is known about the impact of LS on PCK as argued in the introduction, the first method would have to allow for an overall comparison between the CSP and INT conditions judged from a PCK theoretical perspective. This would provide overall knowledge about the impact of LS and CoRe, although without describing the reasoning behind and the quality of found differences. The second method could then try to elucidate the reasoning behind and the quality of significant findings from parts of the PCK construct though depicting the whole process of planning, conducting and reflecting in a holistic manner. This would create a funnel effect, from general to specific descriptions, which is a strength. However, it would also limit the extent to which this research could argue for changes for possible PCK development among PSTs. Specifically, it means that neither of the methods depicts PCK development in full, but rather they relate to parts of the process or part of the construct. This is, however, a necessary tradeoff to make within the limits of this research and similar tradeoffs are echoed within the literature on PCK (Friedrichsen, Driel, & Abell, 2011).

The choice of method further limits the data that can be examined during this research to steps 2–4 (Table 1, p. 54). The reason is that the two conditions during steps 4–6 (Table 1, p. 54) are no longer comparable, since the CSP teaches a new lesson, while the INT group teaches an revised version of the same lesson. It should therefore be acknowledged that other information could result from further investigations into the LS cycle. Furthermore, the study design does not allow for a clear separation of the individual effects introduced by the use of the LS method and the CoRe tool.

Research questions for Articles 1 and 2

For the reasons mentioned above, I have decided that the focus of Article 1 is on 'Comprehension' and 'Transformation' (Figure 2, p. 28), step 2 (Table 1, p. 54), while the focus of Article 2 is on 'Reflecting' and building 'New Comprehension' (Figure 2, p. 28), step 4 (Table 1, p. 54). It thus follows that these two articles do not cover the whole process of pedagogical reasoning and action, but rather use the starting and ending steps to delve into overall differences and similarities. As such, both Articles 1 and 2 compare concerns from field practice conducted according to the regular Norwegian guidelines (CSP condition) with field practice conducted using the combination of LS and CoRe (INT condition). This is accomplished by using the PCK framework to depict which aspects of PCK are of concern during the PSTs' planning of a lesson and their expressed reflections after having taught or observed the lesson. The research thus describes differences and similarities in the PSTs' general focus (for further description, see sub-section 3.3.2).

Articles 1 and 2 thus ask the following two research questions:

Article 1:

> *"How does the use of Lesson Study combined with Content Representation affect pre-service Physics teachers' potential to start developing Pedagogical Content Knowledge while planning a research lesson during field practice?"*

Article 2:

> *"How does the use of Lesson Study in combination with Content Representation affect reflections during mentoring on a taught field practice lesson in Science, judged from a theoretical perspective of PCK?*

Research questions for Articles 3 and 4

Whereas Articles 1 and 2 describe general differences from a theoretical perspective, Articles 3 and 4 aim instead at providing a holistic description of the reasoning behind and the quality of two of the most important differences found in Articles 1 and 2. Articles 1 and 2 thus work as a lens that focuses the research for Articles 3 and 4, thereby allowing them to follow one PCK focus area throughout all of the steps 2–4 (Table 1, p. 54). They thus depict the whole cycle of pedagogical reasoning and action for parts of the PCK construct. Article 3 specifically focuses on the teaching of a learning aim. Article 4 specifically focuses on the assessment of the learning aim researched in Article 3 (for further description, see sub-section 3.3.2). In these two articles, the term 'student teachers' is used instead of 'pre-service teachers'. This was due to journal preferences for terminology. The two terms are used interchangeably.

Articles 3 and 4 thus ask the following two research questions:

Article 3:

> *"How do student teachers of science plan, conduct and reflect on the teaching of a chosen learning aim when using the Lesson Study method in combination with the Content Representation tool?"*

Article 4:

> *"How do student teachers of science understand and implement assessment of and for learning, while using the Lesson Study method in combination with the Content Representation tool?"*

By using this overarching approach to examining the main research question, I argue that information will be acquired about 'Teacher Professional Knowledge & Skill' (TPK&S) (presented in Figure 5, p. 37), in the following ways. Article 1 shows how the PSTs express their PCK as filtered through beliefs, orientation, prior knowledge and context, when actively engaging with the components from TSPK in forming a lesson plan for a specific context. Article 2 shows how the PSTs express their PCK, as filtered through beliefs, orientation, prior knowledge, and context, when actively engaging with reflections around the components of TSPK after having taught the lesson. Articles 3 and 4, in addition to covering the two above steps, also cover the stage of the transformation of the planning into classroom instruction, including assessment. In this way, they further depict how PCK, as filtered through beliefs, orientation, prior knowledge and context, is enacted. Skills are thereby added to PCK, which gives insight into the more elusive PCK&S and how it is connected to the PTSs' expressed PCK. I suggest that this way of framing the overarching approach will provide answers to the research question, as well as add valuable knowledge to the identified research gap.

3.2 Research conditions, data collection and participants

This section explains in detail and discusses the specific research conditions within the subject of science as part of the TasS context. First, it briefly describes teacher education in the Norwegian context. Second, it describes and discusses mentoring as practised during the CSP condition. Third, it describes and discusses how LS combined with CoRe was introduced into field practice together with the pre-planning carried out prior to the data collection steps. Fourth, the three specific steps that this research covers, and the data collection, are described through contrasting the CSP and the INT conditions. Finally, a description and discussion of the selection of participants follows.

3.2.1 Norwegian teacher education

The research is set within a Norwegian educational context that differs from other contexts and thus needs to be explained. Therefore, the following sub-chapter briefly explains the organization and structure of Norwegian teacher education together with the rules that guide field practice.

Afdal (2011) argues that within the Nordic countries there are two different main directions in the organization of teacher education programs. These are the 'researched-based' and the 'general professional' programs. The research-based programs are often associated with Finland, while the general professional program was until recently the common model in Norway. Niemi and Jakku-Sihvonen (2006, p. 40) summarize the three core aims in the research-based program. First, teachers need profound knowledge of the most recent advances in research on the subjects they teach, of how something should be taught, and of interdisciplinary research on the two. Second, teacher education itself should be an object of study and research. Third, teachers should internalize a research-oriented attitude towards their work. These are in sharp contrast to general profession programs which, according to the Norwegian curriculum guidelines (Ministry of Education, 2003), aim to "Qualify the PSTs for work as teachers in compulsory education, and to promote personal development". Furthermore, the program is described as "vocational and practice based".

In 2010, however, a new program was introduced in Norway. This model was based on the Finnish model (Østrem, 2009), and introduced distinctive programs focusing on teaching either grades 1–7 or 5–10. As such, the research base for teaching should receive greater focus. However, Afdal (2011) argues that collective habits, practices and logics do not change overnight. The latter is important since data for this study was collected during years 2012 and 2013.

A comparison of the educational structure of grades 1–7 and 5–10, both of which are part of this study, shows that they are fairly similar. However, there are some major differences. One of these is the need to focus on both Mathematics and Norwegian in grade 1–7, comprising 60 ETCS in all, while one of these two is chosen as a specialization in grade 5–10, comprising 60 ETCS. Another major difference is in the focus on the age groups, which would be expected to be especially differentiated within the general pedagogy courses. The extent to which differentiation has been implemented, however, has not been researched (Afdal, 2011). A third major difference can be found in the focus when teaching subject-matter classes, such as Natural Science. However, in several educational contexts, including the one studied, both grades 1–7 and 5–10 PSTs were taught in a common class due to low overall numbers of PSTs. Teaching in common classes inhibits the teacher educator from fully implementing differentiated teaching, thereby limiting the actual difference between the two groups.

As a part of the PSTs' four-year education to qualify as teachers, the PSTs need a total of 100 days of field practice at partner schools. 15 of these days were covered during each of the conditions included in this study. In each of these periods, both the field practice site and the members of the field practice group change. Mentoring is specified as compulsory in the Norwegian Curriculum Regulations (Ministry of Education, 2010), although no reference is made to the purpose, extent or practice of mentoring during field practice. Therefore, great differences in mentoring can be expected. However, the regulations specify that mentors should be qualified in mentoring, a qualification provided through teacher education courses (See, Hansen, Fausker, & Garborg, 2012). The qualifications therefore work as a somewhat unifying factor for how mentoring is conducted.

3.2.2 CSP condition, year 2012: Describing mentoring during regular field practice

Research has found that Norwegian mentoring teachers are at present greatly influenced by the reflective model developed by Handal and Lauvås (1987), which also applies to other Nordic countries (Sundli, 2007). In fact, the most recent book by Lauvås and Handal (Lauvås & Handal, 2014) can be found on the curriculum that the specific researched teacher education site uses when educating mentoring teachers.

In short, the reflective model was developed as a reaction to the focus of mentoring in the 1970s on model-thinking and pre-service instruction (Bue, 1973), and is based on the work conducted by Schön (1983, 1987). Therefore, mentoring teachers are to focus on PSTs' own practical theory as a base for understanding and developing their teaching practices and are to enhance reflection on the mentee's own terms, while also assessing them (Sundli, 2007). The impact of this model is to emphasize "*pre-supervision, meta-communication about situation and role, exemplary analysis, by attempting to show the general through the specific or special, and to promote a socially secure but professionally challenging situation*" (Sundli, 2007, p. 203). Furthermore "*discursive, non-suppressive, power-free communication and symmetrical relationships are described as the main condition for successful mentoring*" (Sundli, 2007, p. 203).

Furthermore, in order to ensure quality, mentors need to assess the PSTs' levels. This is, however, problematic in the view of Lauvås and Handal (2000). They argue that instead of assessing the act of teaching, evaluation should be used as a form of inquiry into the ways that PSTs think about teaching. It has been found that mentor teachers aligning with this view ask questions based on written lesson plans as a way of clarifying PSTs' values, reasons and actions, and that they use the answers as a basis for their evaluation (Ottesen, 2007). Thus, practical knowledge may lose out to formal knowledge in this respect and it may be said to represent a focus on the more cognitive processes rather than the affective (Sundli, 2007).

In sum, both assessment and guidance for how PSTs can make progress in their work and understanding, thus hinges on the PSTs' ability to reflect and be reflective about their own practices. Noticeably, no aims are put forth for the content or quality of the reflections.

Research looking into the CSP mentoring condition during the TasS project provides findings that seem to indicate that the reflective model was used during mentoring. For instance, Helgevold et al. (2015) found that some written lesson plans are present, and that these are used as a basis from which to ask questions about the PSTs' reasoning and actions. Most of the reflections are directed towards what the PSTs wish to do and why. The author's own understanding, gained through intensive research on the video material, supports these findings (Juhler, In review, 2016). Specific descriptions of the role of the mentors and PSTs during field practice can be found in sub-section 3.2.4. The model, however, not only influences mentoring during the CSP, since the mentoring teachers during the INT have also been introduced to the same education. However, in addition to this education, they received further education, as explained in the next sub-section.

3.2.3 INT condition, year 2013: Introduction of LS combined with CoRe and the pre-planning

Prior to the data collection phase, the mentor teachers and PSTs were introduced to the intervention, more specifically to the LS method and the CoRe tool, and how these in combination should be used during the coming field practice period. During this phase, they also started to plan the research lesson they were to teach. The theoretical lens of PCK was in this respect only used by the researchers, and was therefore not explained. The preparation for the intervention and introduction of LS and CoRe was done through five specific tasks, which are chronologically described in the following. The planning for the tasks was based on prior LS theory and discussed at TasS meetings so as to reduce individual researcher influence. However, some personal preferences and understandings can have been conveyed, especially during the introduction of the CoRe, since this was only discussed by the two science researchers.

The first task was for the researchers and mentor teachers to decide on which theme the PSTs were to teach during field practice in order to compare the way this theme is taught in two different classes. This was important since subsequent tasks would depend on this specific theme. The theme chosen for both groups of PSTs in physics was energy. However, within this theme, the PSTs, together with their mentor teacher, were free to decide which research problem to focus on.

The second task was the introduction of both LS and CoRe, which was carried out by researchers from TasS who were specialists in science. First, the mentor teachers and PSTs were presented with general theory about LS (build on Lewis, 2002) and CoRe (Loughran et al., 2012, pp. 7–23). Second, they were shown examples of how these have been used (Loughran et al., 2012, pp. 117–127; Stigler & Hiebert, 1999, pp. 25–54). Finally, these examples were discussed in both groups and in plenary. Following the discussion, the mentor teachers and PSTs were presented with scaffolding material for the INT. This entailed a translated CoRe form and an LS manual, developed specifically for a Norwegian context by the researchers in TasS. This manual has now been elaborated on and published (Munthe et al., 2015). Additionally, the mentor teachers received theoretical articles focusing on the CoRe and the theme of "energy". Specifically, they were given the introductory chapter to CoRe (Loughran et al., 2012, pp. 16–19), a filled-in CoRe for force (Loughran et al., 2012, pp. 118–137), a chapter about misconceptions about energy (Driver, Squires, Rushworth, & Wood-Robinson, 1994, pp. 138–147), and a chapter about teaching energy (Andersson, 2001, pp. 151–164).

The developed LS manual had several main objectives, which were described through four sections. The first section explained the specific goal for the TasS intervention and the general design of the data collection. The second section focused on the explanation of LS, which specifically emphasizes the importance of developing a good research question, guided by predictions and observations about and from practice. The third section explained the specific steps of the intervention, together with the important focus areas within each step. The fourth section was a scaffolding section that presented different forms that might help the mentor teachers and the PSTs during the different steps. This section also presented specific questions for each step that could be important for the mentor teachers and the PSTs to focus on.

The purpose of this was thus to provide both the pre-service and mentor teachers with a good understanding of LS, CoRe, their aims, and the process leading to the fulfilment of these aims.

The third task was for the PST group, prior to the field practice, to interview their mentor teachers. This was done as a part of their preparation for the development of the lesson plan. This interview was framed on the LS handbook, which presented several questions that the PSTs were asked to enquire about. All of these questions were aimed at the specific theme of "energy". The questions were as follows:

- What is difficult for the pupils?
- Which misunderstandings do the pupils have?
- Which typical mistakes do the pupils make?
- What ideas are there about specific ways of teaching the theme?
- How do you find out what the pupils are already able to do and know?

From the answers obtained, the PSTs were told to make and hand in a reflection note of approximately 1.5 pages long, describing what they had learned through the interview. This was done to give the PSTs an opportunity to build on the mentor teachers' experience from the classroom and about the specific pupils. The aim of this step was to make the PSTs figure out what they wanted to focus on as a research question in relation to specific classroom problems. This step therefore covers the key feature 1.a (research goal) and parts of key feature 1.b (investigation), as described in Figure 6, p. 44-45.

The fourth task first aimed at articulating a LS research question about the given theme as a group. Second, in connection to this LS research question, an exploration and examination of the official curricular plans (Utdanningsdirektoratet, 2006), and the aims described in the plans, were to be conducted. During this task, the PSTs as a group effort were to find specific curricular goals for the theme of 'energy' for the specific class level they had to teach. Furthermore, they were asked to make a material research of different curricular books. The intent here was to create specific knowledge about the energy theme for the specific class level, as well as generate general knowledge about how the theme of energy is taught and progresses before and after the class level they were to teach. The PSTs were told that the result of this research should be the development of a preliminary lesson plan for the theme of energy. They had to fill in and describe these preliminary plans through a lesson form provided in the LS manual. Furthermore, they had to work through and fill in a CoRe form for the lesson focused on energy.

As such, this task continued the investigation into the research aim started in the third task. It thus finished 1.a (research goal) and the remainder of key feature 1.b (investigation) and started to cover key feature 1.c (planning), as described in Figure 6, p. 44-45. The remainder of the steps 1.c, 2. a-b and 3. a–c are described during the data collection steps.

The fifth task unfolded just before the start of the field practice period, during which the two researchers and the two mentor teachers met. Here they worked as a group and filled in a CoRe template in detail that focused on the teaching of energy. However, the specifics of this CoRe turned out to be somewhat different from what the PSTs chose to teach during field practice. The aim of this meeting was to ensure that the mentor teachers gained a deeper understanding of how to use the CoRe form so that they would be better prepared to challenge and collaborate on developing the preliminary plans during mentoring. The PSTs were tasked with developing these plans.

The researchers from this stage onwards only assisted in clarifying questions. The questions received were mainly connected to the material handed out and the specific steps in the LS process.

3.2.4 Description of the data collection steps

This sub-section describes the CSP and the INT during each of the three data collection steps that this research covers, so that similarities and differences between these become clear. This information is needed to understand the research contexts, which in turn relates to the methods of analysis (section 3.3), and which again influences the quality of the study (section 3.4) and necessary ethical considerations (section 3.5).

The described data collection steps relate to Table 1: ‘Data collection for TasS’, p. 54, and cover step 2: Pre-mentoring with mentor and PSTs, step 3: Research lesson taught by PSTs and step 4: Middle mentoring with mentor and PSTs. The reason for selecting these three steps is provided in sub-section 3.1.2. Step 4 was split into post- and pre-mentoring during the CSP, since the PSTs first reflected on the lesson taught (post-lesson mentoring) and then later planned a new lesson (pre-lesson mentoring). During the INT the process was kept together, since the group reflected on the taught lesson as a basis for teaching the same lesson to a new group of pupils in an revised version. For comparison reasons, only the post-mentoring from CSP is therefore considered here.

Each of the steps was video-recorded. Steps 2 and 4 were recorded by the participants themselves and later given to the researchers. Step 3 was recorded by the researchers, who used one steady camera showing the whole classroom, and one mobile camera that followed the teacher around the classroom.

Step 2: Pre-mentoring with mentor teacher and PSTs

Before teaching the lesson the first time, a pre-mentoring session was carried out. The aim of this session was somewhat different in the CSP and the INT.

During the CSP, the PSTs had some ideas about what to teach when they came to the pre-mentoring session. These ideas were written down on an antennary that covered the main structure of the lesson. During both sessions two curricular books were present on the table and most had paper on which to write notes, although these were little used. In both cases the mentors took control of the conversation and directed the reflections towards the content of the antennary. The conversations were mainly directed towards what the PSTs wanted to do with the pupils during the lesson and in which order (Helgevold et al., 2015; Juhler, 2016). As such, the mentoring teacher on the one hand listened to the PSTs’ explanations about their developed plans for the lesson and on the other asked follow-up questions as a way of getting to the PSTs’ underlying reasoning. Both are consistent with relaying on the reflective model by Handal and Lauvås (Handal & Lauvås, 1987). Overall, the one who was to teach was the most active in the conversation. However, we do not know how this person was chosen. The sessions lasted for about 26 minutes on average.

During the INT, the PSTs came with preliminary plans for the research lesson (see the description of how these were developed in sub-section 3.2.2). The plans were sent to the mentor teacher two days prior to the pre-lesson mentoring session. The PSTs handed in a general overview of the lesson, in addition to a filled in CoRe for the lesson. They also brought different kinds of teaching materials, such as books. According to the LS manual (Munthe et al., 2015), the mentor teacher had the role of being critical and explorative about the choices that the PSTs had made during their pre-planning. They were to focus especially on the connection between the research aim (key element 1.a), investigation (key element 1.b), and how these connected to the choices made during planning (key element 1.c) (see Figure 6, p. 44-45). Furthermore, building on this information, the mentor teachers were to enter into collaboration with the PSTs to improve on their preliminary plans. What could be observed was that the mentor teachers used and followed the LS manual and the considerations specified therein. Furthermore, they used the developed CoRe as a way of getting to talk about content that was connected to the 'big ideas' for the lesson and pedagogical concerns connected to the main research question. These sessions were 42 minutes long on average.

Step 3: Lesson taught by the PSTs

The taught lessons differed considerably between the two conditions, especially when it comes to the role assumed by those who were not teaching.

During the CSP one of the PSTs taught the lesson. In one case the teacher was changed half way through. One of the lessons focused on teaching about energy while the other focused on the teaching of sound. During the lecturing parts of the lessons the PSTs who did not teach were observing, and took some notes during the process. During the experiment parts of the lessons, they instead walked around helping the pupils, thus working as helpers for the one teaching. The mentor teachers mostly observed the lesson and took some notes throughout the lesson.

During the INT, the PSTs, just prior to the research lesson, drew lots for who was to teach. The intention of drawing lots this late was that all of the PSTs would participate equally during the planning stage in this way. In the LS manual, it was stressed that the person teaching the lesson had to try to stay true to what the group had planned. Those PSTs who did not teach the lesson, as well as the mentor teacher, were designated observers. They gathered observations by walking around, i.e. listening to pupils' answers and taking detailed notes about what they saw and heard. However, they were not allowed to interact with the pupils during the lesson (Munthe et al., 2015). This thus covers key element 2 a-b of Figure 6, p. 44-45. Just after the lesson, each of the PSTs during the INT conducted a short interview (max 10 minutes) with one pupil. The pupils were chosen based on predicted behaviour and learning patterns tied to expectations about low, medium and high achievement. These predictions were developed in collaboration between the PSTs and the mentor teacher. The questions asked were aimed at uncovering additional information about the pupils' learning process that puzzled the observers during the taught lesson and that could give a better understanding about the group's main research question. In turn this information would be used when revising the taught lesson (Munthe et al., 2015). The individual interviews were not recorded and notes were not gathered, a decision made by the TasS group.

Step 4: Middle mentoring with mentor and PSTs

The CSP reflection step was observed to be led by the mentor teacher. The content was teacher-centred and mainly focused on instructions and classroom management as reported by Helgevold et al. (2015) and Juhler (In review). This might be a reason why observations from the classroom were only used to a small degree during the conversations. It was further observed that the PSTs who had taught the lesson were the most active in the conversations, which lasted 19 minutes on average.

According to the LS manual, the aim of the INT middle mentoring session was to assess the taught research lesson, but also to improve it, since an revised version was to be taught to a new but similar class. Therefore, the LS manual stressed that assessment should be based on observations collected throughout. This evidence then had to be used to identify elements that could be improved, as compared to teaching aims, and to further inform the main research question for the research lesson (Munthe et al., 2015). This thus covers key element 3 a–c of Figure 6, p. 44-45. It was found that the content was pupil-centred and mainly focused on how the activities could be taught in a better way and how assessment information was collected during the lesson (Helgevold et al., 2015; Juhler, In review). This was done through discussions between the PSTs and mentor teachers. During these conversations, it could be observed that knowledge collected through observations and interviews with the pupils was actively used when reflecting. On average, these conversations lasted 56.5 minutes.

3.2.5 Description of the participants

The present sub-section presents a description of all of the participants in this study, how they were chosen, and how they were matched up in groups for the INT and the CSP. This knowledge is important as it has implications for the quality of the study (section 3.4) and ethical considerations (section 3.5). The participants of the study were all PSTs at a specific Norwegian University or mentor teachers connected to this specific university. Each year, 30–35 PSTs study science at this university. Although the TasS project group strongly recommended the project to all of the PSTs, only a few PSTs volunteered to participate. The same was true for the mentor teachers. Therefore, the selection method of the PSTs and mentor teachers became one of convenience instead of, as originally intended, a randomized choice (Johannessen, Tufte, & Kristoffersen, 2006).

In both the CSP and INT, the participants worked in two groups. One group consisted of three PSTs plus a mentor teacher, while the other consisted of four PSTs and one mentor teacher. The grouping of the participants during the two years is shown in Figure 8.

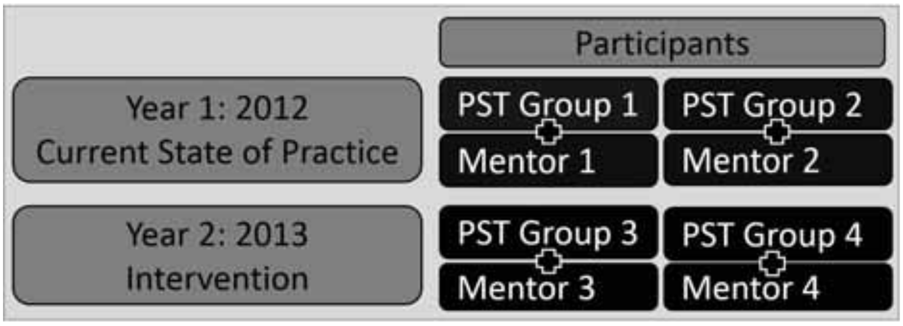

Figure 8: Participants for the TasS project within the physics subject

To assemble groups, the administration first divided the PSTs into clusters, which were based on both subject focus and grade focus. Second, they were randomly divided into groups, which consisted of either three or four PSTs. Third, the individual groups were allocated a mentor teacher who taught the specific subject. In addition to the pre-service and mentor teachers, two TasS researchers who were science lecturers joined the project for both years.

PST group 1 consisted of three females and one male in their early twenties who specialized in teaching grades 5–10. During field practice, they taught 10 graders. PST group 2 consisted of three females, two in their early twenties and one around forty, who specialized in teaching grades 1–7. During field practice, they taught 5 graders. PST group 3 consisted of four females in their early twenties who specialized in teaching grades 1–7. During field practice, they taught 7 graders. PST group 4 consisted of two males and one female in their early twenties who specialized in teaching grades 5–10. During field practice, they taught 10 graders. The mix of participants gave a ratio of one male to four females, which is indicative of the wider cohort within science at this specific teacher education. The participants for CSP (PST 1 & 2) were in their third year of teacher education. The participants for INT (PST 3 & 4) were in their second year of teacher education, since the study model for teacher education had changed. This means that the CSP participants have 15 ETCS more pedagogy, 30 days more field practice experience, and 5 out of 7 had 30 ETCS more in science subjects, than those in the INT. From this it can arguably be expected that the participants from the CSP will express more sophisticated views and be better to transform planning into practice than the participants of the INT. All groups during the INT and CSP had shortly before the field practice partaken in an 8 week course in chemistry, geology and technology. None of the groups had, however, yet received their teaching in physics.

The mentor teachers differed somewhat in age. Mentor 1 was in the thirties. Mentor 2 was around sixty. Mentor 3 was around forty. Mentor 4 was around forty. The four participating mentor teachers were all qualified teachers. However, they had a varied background with regard to qualifications in mentoring and years of experience as mentor teachers.

A main question that arises from how the participants were chosen and their differences, especially in relation to Articles 1 and 2, is how comparable the four groups are. To figure this out, Articles 1 and 2 looked into the discovered tendencies within the two CSP groups and the two INT groups, and compared these. What was found was that the reported average tendencies in both cases was the same as when looking at the tendencies found in each individual group (Juhler, In review, 2016). This shows that individual group differences were smaller than that of the influences of the CSP condition and of the INT condition. However, since only one member of each group taught the lesson, individual differences in this case may be expected to have been much higher.

3.3 Methods of analysing data

This section builds on the descriptions provided and the discussions in the two previous sections, and focuses on how the data for the four articles were analysed and fit into the overarching research design. It first discusses the main analysis paradigm used, and rationalizes the choice of this in light of arguments expressed in section 3.1, 'Overarching research design', and section 3.2, 'Research conditions, data collection and participants'. The two specific methods of analysis used for Articles 1 and 2 and Articles 3 and 4 are then described and contrasted in light of the research questions aimed to be answered, as presented in sub-section 3.1.3, 'Research questions'.

3.3.1 Main analysis paradigm: Qualitative content analysis

This sub-section will present the reasons why a qualitative content analysis method was chosen as the main paradigm from which to analyse the data for the four articles.

The choice of the main analysis paradigm was primarily based on the kinds of data collected in this study. These were video-recordings of groups collaborating while discussing the planning and reflection on a lesson, as well as how the lesson was conducted. The choice was also closely related to what evidence would be needed to answer the main research question. In light of this, a qualitative methodology specifically using content analysis was found to have some clear advantages which cannot become covert in the same way compared to using quantitative methodology

One advantage of these choices is that qualitative content analysis is focused on the richness of data, which springs from a design meant to uncover the latent meaning of different phenomena by deep conceptual mining (Merriam, 1988). Another is that qualitative content analysis is reasonably flexible, since it is able to be applied to virtually any form of linguistic communication. It thus becomes a very potent method for examining human behaviour, emotional reactions, and other human-related aspects (Babbie, 1992). Furthermore, this methodology has the possibility to handle and elicit knowledge from vast amounts of unstructured data, i.e. by means of the data condensing categorization process, so that it can uncover the social reality of the phenomena being researched (Patton, 2002).

Within qualitative content analysis, one can either carry out inductive or deductive coding, depending on the aim of the research (Marshall & Rossman, 1995; Robson, 1993). Since this research both relies on and aims to study the intervention in light of prior theory, namely PCK (section 2.3), a deductive approach was consequently chosen. The main strength of this choice lies in the fact that it makes the analysis systematic and logical since the categories are operationalized based on already known theory or knowledge within a field of research (Kyngäs & Vanhanen, 1999), thus lending trustworthiness to the analysis carried out. Furthermore, since the research had the potential to extend the conceptual framework of PCK, the categorization of definitions should in turn be influenced inductively by the data (Zhang & Wildemuh, 2009). This ensures that the coding becomes as internally homogeneous as possible and as externally heterogeneous as possible (Lincoln & Guba, 1985), so that the categories become mutually exclusive and exhaustive (GAO, 1996).

Certain limitations follow the use of theory to approach the analysis. First, it makes it more likely to find evidence that is supportive rather than non-supportive of the theory used. Second, a focus on theory could potentially ‘blind’ the researcher to contextual aspects of the phenomenon (Hsieh & Shannon, 2005). For these two reasons, it is important to present findings and interpretations in separate sections, since interpretations in this respect represent my personal and theoretical understanding of the phenomenon under study (Zhang & Wildemuh, 2009). Furthermore, the reader needs to be presented with a description clear enough to allow him to gain a sufficient understanding of the basis for the interpretation, and a sufficient interpretation to allow the reader to understand the description (Patton, 2002).

Within the qualitative content analysis approach, two distinct approaches were needed, as argued in sub-section 3.1.2. One was for Articles 1 and 2, using data steps 2 and 4 (see Table 1, p. 54), since these articles aimed at describing general tendencies within and between the two research conditions. Another was for Articles 3 and 4, using data steps 2, 3 and 4 (see

Table 1, p. 54), since these articles aimed at providing rich descriptions of the main findings from Articles 1 and 2 throughout the whole process. Therefore, the specific method of analysis used for Articles 1 and 2 was chosen to be an unconstrained deductive content analysis (Elo & Kyngäs, 2008), and the method of analysis used for Articles 3 and 4 was chosen to be a stepwise approach to content analysis (Boeije, 2009). In the following sub-section, the two specific ways of using content analysis will be described and contrasted in light of the research aims.

3.3.2 Contrasting the two analysis approaches

The present sub-section aims to give a brief overview of the two analysis approaches used. It does so by contrasting the two approaches as related to the research questions they aim to answer. The descriptions will therefore not be exhaustive. Full descriptions of each specific method can be found in Appendix F, G, H and I.

An overview of the similarities and dissimilarities in the two approaches is provided in Table 2: 'Contrasting the two analysis approaches used for the four Articles'. The steps in the left hand column are based on the descriptions of content analysis given by Elo and Kyngäs (2008).

Table 2: Contrasting the two analysis approaches used for the four articles

<table>
<tr><th></th><th>Articles 1 & 2: What was done</th><th>Articles 3 &4: What was done</th></tr>
<tr><td>Prepare data</td><td colspan="2">Texts were transcribed and verified by a second researcher who read all the text</td></tr>
<tr><td>Make sense of whole</td><td>• See all video
• Study transcripts</td><td>• Study LS plan and CoRe form.
• Study pre-mentoring session
• Add additional aspects to CoRe
• Identify which 'big ideas' and which pedagogical considerations the PSTs intended to focus on.</td></tr>
</table>

Narrow the scope	• The four base categories chosen from the Magnusson et al. (1999) model	• Main findings from Article 1 & 2: Pupils' learning and assessment. • Focus on first big idea and three activities.
Define unit of analysis	• Thematic unit chosen • Coverage segments of utterances. However, single sentences in a few cases.	
Develop coding category and schemes	• PCK theory used: o Main codes: Magnusson et al. (1999, p. 99, see Figure 4 p. 33) o Sub-codes: Descriptions from Magnusson et al. (1999, pp. 103–105) and Lannin et al. (2013, p. 9)	• From the extended CoRe and LS aims three broad categories stood out: One, the 'Problem of teaching transfer of energy'. Two, 'Stressing terms and concepts'. Three, 'Assessment'.
	• Develop coding manual containing category names, definitions, rules for assigning codes, and examples (Weber, 1990).	
Coding of text, inductively change coding scheme	• Code one transcript (NVivo) • Discuss with second researcher, make clarifications. • Update coding manual • Code all transcripts (NVivo)	• First author coded all transcripts, NVivo. • Second author checked all coding. • First author made descriptions from coding, by combining pieces that fit together.
Assess coding	• Inter-coder agreement test (NVivo) o Percentage agreement 91,4% o Sub-codes over 80 %, except C4 • Corrected focusing on C4	• Second author checked all descriptions with initial coding • Changes to the initial descriptions were made.
Draw conclusions	• Calculate main and sub-category percentages	• Present thick descriptions

from the coded data	o Number of words in each transcript divided by number of words coded to each category. • Present as tables and cake diagrams	• Compare descriptions with research findings from planning, instruction and assessment as typically found and when using either LS or CoRe.

As seen in the above table, many of the steps are the same in the unconstrained deductive content analysis (Elo & Kyngäs, 2008) and the stepwise approach to content analysis (Boeije, 2009). However, the rationale behind what is done in each step differs.

First, the data, in both cases, needed to be *prepared for analysis*. This was done by making transcripts of the video sequences. The transcripts in full were verified by a researcher from TasS, in addition to the original transcriber. This was done to ensure their accuracy and trustworthiness.

Second, it is important to *Make sense of whole* (Burnard, 1991; Tesch, 1990) in order to determine what is happening (Morse & Field, 1995). Articles 1 and 2 achieved this by studying the video-recordings and transcripts. Both sources were used to gain a comprehensive and complementary picture of the data. Articles 3 & 4, in contrast, used the developed LS and CoRe plans to look into the pre-mentoring sessions with the aim of identifying pedagogical considerations that the PSTs intended to focus on and that was connected to the main findings from Articles 1 and 2.

Third, it is important to *narrow the scope* of the analysis. This narrowing down of the scope for all four articles relied on the need to show the development of PCK, as argued in section 3.1. To compare the INT and the CSP (Articles 1 and 2), it was decided to use only the four base categories of Magnusson et al.'s (1999) model, leaving out orientations, a decision based on considerations about mutually exclusive and exhaustive categories (GAO, 1996). In order to consider the quality of and reasoning behind two of the most interesting findings presented in Articles 1 and 2 (see section 3.2), Article 3 was chosen to focus on pupils' learning of one big idea and Article 4 on assessment of the same big idea (Juhler, In review, 2016). To narrow the scope further, it was decided only to look into the CoRe forms first ‘big idea’, namely ‘energy transfers’. The reasoning was that ‘big ideas’ build on each other, thus making the first idea function as a gateway to subsequent ideas (Loughran et al., 2012). Furthermore, it was also decided only to focus on the three practical activities: ‘Newton´s cradle’, ‘Rubbing of hands’ and ‘Shooting with a catapult’, from the taught lesson. The reason was that the three activities, according to the filled in CoRe, covered the teaching of the first ‘big idea’ and learning aim ‘energy transfers’, as well as assessment of that learning aim.

Fourth, *units of analysis* needed to be chosen. In all four cases, these became thematic units (Downe Wamboldt, 1992). The reason was that all the articles tried to depict certain themes through the coding of categories. In order to keep themes together, it was decided to principally code whole segments of utterances, while single sentences were coded in a few cases.

Fifth, *development of coding categories and schemes* was needed. In all cases, prior PCK theory was used to develop initial coding categories, a choice based on considerations about the research aim (see section 3.1). Articles 1 and 2 relied on Magnusson et al.’s (1999) model of science to create four main coding categories, these were again divided into a number of sub-categories. The initial definitions of the sub-categories were based on descriptions of each of the four main categories provided by Magnusson et al.’s model (1999, pp. 103–115), as well as Lannin et. al.’s (2013, p. 9) 24 codes developed for the same model. The aim was that the coding scheme then would provide both overarching tendencies and describe the tendencies within each main category. This would happen through a comparison of the CSP and INT conditions when planning and reflecting.

Articles 3 and 4, on the other hand, aimed at making detailed descriptions of the teaching of a learning aim and assessment of that learning aim through the whole process of planning, conducting and reflection. To create the coding categories for these two areas, an extensive reading of the PSTs’ filled in CoRe, together with the transcript from the planning session was done. During the discussions from the planning process, several new aspects were mentioned which were not stated in the filled in CoRe. These were subsequently added to the CoRe. From this extensive reading, three broad categories covering the two main areas for Articles 3 and 4 were developed. These were based on and combined content described in the corresponding PCK sub-categories', extended CoRe categories, including the PST descriptions and their expressed LS aims. The three specific codes were: The 'Problem of teaching transfer of energy', 'Stressing terms and concepts' and 'Assessment'.

In both cases, this led to the development of an initial coding manual that contained names, definitions, rules for assigning, and examples of codes (Weber, 1990).

Sixth, *coding of text and inductively change coding scheme* was carried out. In both cases, the initially developed coding manuals were used to code a piece (Articles 1 and 2) or the whole sequences (Articles 3 and 4) of text and then discuss it with a second researcher. In light of these discussions, changes and clarifications were made inductively to increase the accuracy of the predetermined categories (Hsieh & Shannon, 2005).

In the case of Articles 1 and 2, several sub-codes were found difficult to distinguish from each other, and in these cases codes were merged together and definitions were updated. In other cases, only definitions and descriptions were updated. This resulted in four sub-coding categories for each of the four main categories, designated A1–4, B1–4, C1–4 and D1–4. In the case of Articles 3 and 4 only definitions and descriptions were updated in order to make inclusion and exclusion from the categories clear. After a sufficient level of consistency had been achieved, the updated coding rules were then applied to the entire corpus of texts for Articles 1 and 2 and updated for Articles 3 and 4 (Zhang & Wildemuh, 2009). The final coding scheme for Articles 1 and 2 can be found in Appendix B and C, and coding examples can be found in Appendix D.

In the case of Articles 3 and 4, however, one further step was needed since the information at that time consisted of segments of pieces of information coded to a specific category. For this information to be useful, the pieces which were believed to fit together then had to be assembled (Boeije, 2009). Utterances from the three categories concerning the same strand of thought were ordered, thereby identifying four especially interesting parts. These were for Article 1: 'PSTs expressed understanding about what it means to have learned a teaching aim', and 'PSTs reasoning behind instructing in a certain way to achieve this learning'. For Article 2, they were: 'PSTs specific use of assessment tools and their reasons behind their choice' and 'PSTs hypothesis about pupils' responses that can determine learning outcome'. The content of these interesting parts were then reassembled and used to create the descriptions presented in the articles. To prevent the author from impacting the data, the evolving relationship between the categories and of the credibility of those relationships were continuously taken into consideration (Boeije, 2009). Coding examples for Articles 3 and 4 can be found in the text of the articles (see Appendix H and I).

Seventh, an *assessment of the coding* was needed to ensure consistency (Hsieh & Shannon, 2005), validity, and reliability (Schilling, 2006).

To ensure validity and reliability for Articles 1 and 2, a second researcher coded a new piece of material so that an inter-coder reliability test could be carried out in Nvivo (2014). The percentage agreement was an average of 91.4%, with all sub-codes over 80%, with the exception of C4. This constitutes a high and acceptable result, even by conservative standards (Neuendorf, 2002). However, to ensure research validity and reliability for all the sub-codes, the material was studied afterwards and corrected with specific focus on the sub-code C4. Due to the limited data material, significant tests, such as coheres D, were not applicable.

To ensure validity and reliability for Articles 3 and 4, a second researcher checked the descriptions made and compared them with the initial coding results. This resulted in some revisions being made of the descriptions and their content. In this way, both authors agreed that the final descriptions presented in Articles 3 and 4 presented the PST groups' thoughts and motivation in an accurate and neutral way.

Eighth, *conclusions needed to be drawn from the coded data* followed.

Articles 1 and 2 did this by comparing code sizes in percentages, since they give a good indication of the importance of the different codes (Curtis et al., 2001) and furthermore would make it possible to compare transcripts of different lengths. This was done by counting all the words in one transcript (100%) divided by the number of words coded to each category. This data was then presented as tables and diagrams. An effect of this way of calculating, is that one percent in the INT would cover approximately twice as many words as in the CSP. This is due to differences in duration of the mentoring sessions, where 16,923 words were spoken during CSP, while 31,769 words were spoken during the INT. From this, it could be argued that one should have reported number of words coded in each category, thus making clearer differences in category size between the two conditions. However, this would in turn have masked the importance of each code.

Articles 3 and 4 used the developed description. In both cases, prior theory and research covering the specific stage (planning, conduction, reflection), as well as the CSP condition and the INT situation (LS and CoRe), were used to draw conclusions. In this way, conclusions came to bear on prior theory, thus preventing biased subjectivity, while representing multiple perspectives testifying to the fruitfulness and the vigour of the conducted research.

3.4 *Quality of the study*

The present section will look into the perceived quality of the study as it relates to the choices made during the research process explained thus far. To do so an understanding of theoretical underpinnings needs to be investigated. Therefore, the concept of quality in this study is first explained. Second, it specifically describes what the role of 'Methodological accountability', 'Reflection', 'Triangulation', 'Member validation', 'Multiple researchers', and what 'Generalizability' means for quality in this context. These theoretical underpinnings are then used to discuss the choices made and how they consider each of these seven quality measures.

A study's quality is typically related to both reliability and validity. However, discussions about validity and reliability in qualitative studies are not always applicable (Johannessen et al., 2006). Within qualitative research, it is therefore more typical to talk about the quality of the study as a measure instead of reliability and validity. Within qualitative research, the quality of the study is therefore often understood as research that has methodological accountability, reflection on the role of the researcher, triangulation, member validation, and multiple researchers (Boeije, 2009).

Methodological accountability, according to Boeije (2009), means that the researchers document what they have done in an accurate way, how it was done, and why it was done. The reader should be able to judge whether the outcome can be trusted, and be able to repeat the whole investigation if desired. This is typically obtained through describing how the data was handled, how transformation was achieved, and which measures were used to ensure systematic work efforts. It also includes an account of the researcher's perspective: theoretical starting point, research question and purposes. It is expected that these elements would have guided the decisions during data collection in a logical way. Furthermore, it typically also includes replication, although this remains difficult within qualitative research. Therefore, methodological transparency is regarded as an alternative, since it at least enables a virtual replication. A virtual replication dominantly serves to assess the justification of the researcher's choices and line of reasoning, thus facilitating possible replication and comparative studies (Seale, 1999).

Methodological accountability has been accounted for in this project in Chapter 4, where data handling and transformation were explained, as well as how they were systematized. Furthermore, Chapter 3 and the start of Chapter 4 account for the researcher's perspectives, starting point, and purpose. In these ways, the research aimed at transparency.

Reflection on the role of the researcher, according to Boeije (2009), includes that researchers deliberately choose their role according to how it best fits with what they want to achieve. Within qualitative research, this kind of involvement from the researcher is hard to avoid since elicitation of participant motivation, thoughts or acts, has to be carried out through the presence of a researcher in some way. One effect of this involvement is that participants can change their behaviour when they know they are being studied. This phenomenon is called 'reactivity' and influences validity negatively. However, it is also believed that the participants fall back on old patterns when exposed to research over a prolonged period of time (Patton, 1999). Participants can also influence the researcher. A known effect of this is that the researcher can become naive and biased, thus having difficulty reflecting theoretically on their area of interest (Patton, 1999). Therefore, it is important to be reflective about how data is interpreted, about the role of the researcher during the analytic process, and about preconceived ideas and assumptions held that influence the analysis (Mauthner & Doucet, 2003). While research cannot be value free, it can nevertheless be non-judgmental and reflect possible influences, thus strengthening the validity of the research.

In sections 3.1 and 3.2, descriptions of deliberate and reasoned choices were given for the researcher's role throughout the study. Section 3.2 also showed how reflections about the role of the researcher's ideas and assumptions may possibly influence the study and how these have been limited. Furthermore, since the project lasted over a prolonged time period, and both groups were treated in the same way, the impact has aimed to be minimized. Chapter 2 focuses on the theory that the analysis in section 3.3 relies on, so that values are clearly stated and personal judgment is limited.

Triangulation refers to the examination of a social phenomenon from different angles (Boeije, 2009). This means that more than one method or source of data in a research endeavour should be used (Bryman, 2008). Using different methods and data enhances the researcher's ability to observe the phenomenon in question with greater accuracy and supplies a richer view. The point is not to use the different kinds of data or research methods to demonstrate that they essentially give the same result. As with a consistency check, this is a common misunderstanding (Patton, 1999). Somewhat different outcomes need not be seen as disturbing, but should rather be used as a challenge to gain a better understanding of the relationship between the topic under study and the methods used.

In Chapter 4, two different methods of data analysis, several points of data collection, and different data sources, were explained in detail. Data triangulation was used in specific ways in the project so that greater accuracy and a richer view could be obtained.

Member validation, according to Boeije (2009), is known as feedback to participants or member checks. The assumption here is that if participants are presented with data and findings from the study which they recognize and judge to be correct, this contributes to the verification of the study (Cutcliffe & McKenna, 2002). One way of doing so is to have participants read through study results and interpretations. In this respect, it is important that the participants do not need to agree with the researcher's interpretation. One reason is that a researcher often has another theoretical point of view from that of the participant. Another is that participants may have interests in the field which are at odds with the outcomes of the study (Forbat & Henderson, 2003).

To carry out a member validation, this study invited two of the participants from the INT to read through and comment on Article 3. Article 3 was chosen because this study is one of the two articles which were the most interpretative, and thus possibly could be problematic. However, the two participants found the reading interesting, informative, and a reasonably accurate account of their thoughts and reasoning, as they remembered having them at the time. They therefore verified this article, which adds to the overall quality of the study.

Multiple researchers, according to Boeije (2009), are used to collect the data so that potential bias is reduced. This is also referred to as ’analyst triangulation’ (Patton, 1999). Teams are in general better at fostering a higher level of conceptual thinking, thus raising the analysis to a higher level of abstraction (Barry, Britten, Barber, Bradley, & Stevenson, 1999). Teams are also better at standardizing coding and improving accuracy of the coding process. Furthermore, they are better at avoiding bias because they act as a ’control’ on each other’s interpretations. This is even more true if researchers come from various disciplines, thus bringing different perspectives to the discussions. Working in a team also provides an arena where researchers can learn from each other. These are all aspects that can ultimately benefit the quality of the data. An additional dimension that can benefit the quality of the data is peer debriefing. Peer debriefing is a process where peers or colleagues who are not a part of the research team, provide fresh perspectives on the analysis process and explore explanations that the researchers might have overlooked. This helps to minimize bias even more and to prepare for critique.

Chapter 3 explained that all the data has been collected as a team effort. In fact, in most of the steps people have at least worked in pairs. The researchers within the TasS group worked within different subjects. The TasS group considered this as an advantage since it allocated and used a good deal of time on having people present their unfinished research so that the TasS team could comment on and learn from this experience. Finally, the TasS project included an international team of research members as a reference group. This group met with the TasS researchers for one week during each of the years 2012, 2013 and 2014. During these weeks, they were involved in both discussions with the whole TasS group and individual sessions with researchers. The reference group were specifically tasked with challenging the TasS group’s views and to contribute with their outside perspectives on the research carried out by TasS in a peer debriefing process. The main focus was directed at discussing the TasS project, the members' chosen methods of analysis, and the results and discussions following from this, thereby covering both overarching and specific perspectives. In these ways, multiple researchers were used to reduce bias.

Generalizability, accordantly to (Boeije, 2009), is connected to quality, and is aimed at the main question about whether or not the results can be generalized beyond the research context in which it was conducted. However, in qualitative studies, generalizability is not necessarily an aim in itself; in many cases it is very difficult to obtain. Therefore, it is important that the findings are carefully limited, since one needs to be extremely careful about extrapolating (much less generalizing) the findings to other situations and other people (Patton, 1999). Smaling (2003) distinguishes three types of inductive generalization, namely statistical generalization, theoretical generalization, and variation-based generalization. Statistical generalization is based on random sampling. In theoretical generalization, the researcher theorizes on the basis of a certain sample. Next, the researcher tests the provisional findings and conjectures with new sample cases. In this way the theory is adjusted, refined, expanded and corrected. These findings thus become the 'vehicle' for generalization to other cases not yet studied. Variation-based generalization is applicable when the sample takes the form of a non-theory directed approach. Here, generalization is attempted through describing the variations in which the phenomenon occurs until the variation in the sample has been covered by the sample.

The research presented is very specific. It is for a certain geographical place, within one university, and again within a small number of participants. Therefore, this research cannot be generalized beyond the research context from which it was conducted. However, the research does build on both prior theory and research, which means that it contributes to the adjustment, refinement, expansion and correction within this domain. Furthermore, the findings from the study mostly support previous findings. In this way, theoretical generalization, within the limits of the study, can be claimed.

3.5 Ethical considerations

Research and potential findings from the research always raise ethical questions and considerations. Therefore, it is important to discuss these in relationship to the research conducted and the choices made herein. The present section will therefore discuss ethical considerations concerning: 'Delaying implementation', 'Researching PSTs', 'Anonymity', 'Further implications', and 'Validity'.

Delaying implementation. First we have asked ourselves if it would be ethical to delay the implementation of the INT condition, since we believed it to be superior to the CSP. The answer from the TasS group was a definite 'yes', since a study of a CSP condition was needed to be able to design the INT condition. Furthermore, to be able to assess whether the INT would be worthwhile, a control group was necessary with whom to compare. On the other hand, the INT condition could be quite time-consuming, expensive, and yield fewer outcomes than expected. If this was the case, then it would be unethical to upscale the INT condition (Boeije, 2009).

Researching PSTs. Another aspect of the TasS project that received considerable consideration was the fact that the research would be directed at how PSTs think, reason, judge, learn, relate and teach. To be researched on with these intentions is very personal and can potentially be challenging (Silverman, 2013). Therefore, the TasS group found it very important that we as researchers and teacher educators involved ourselves in the process throughout the two years, thereby becoming equally responsible for the process. By doing so, our thoughts and reasoning would also become part of the research project. In turn it would also make it less likely to blame the PSTs for aspects that did not go according to plan or if effects reported by prior research were not found. Furthermore, the involvement would provide a learning potential for all persons involved in the TasS project.

Anonymity. However, these considerations do not make ethical concerns less relevant about the preservation of the participants' anonymity or the stress that the research might induce (Silverman, 2013). Therefore, permission to collect, store and research such data has to be approved by NSD (2015). This approval was obtained for the TasS project (see Appendix E). The approval builds on our ability to store the data safely, which was done on a secure server that only the researchers on the campus area could access. Furthermore, the data was not to be stored locally and a date for its destruction was set. All transcribed and written material was stored on the same server and was anonymized as early as possible. In this way, the chance of interference with the participants' private lives was minimized (Boeije, 2009).

Further implications. Ethical considerations also applied to the interviews and teaching sequences conducted as part of the research. The participants knew each other and many of the researchers knew the participants, and vice versa, since the researchers were practicing teachers at the university. Therefore, utterances made during the project could possibly have longer-lasting implications, which again could influence how the participants act and what they say (Silverman, 2013). A situation like this might be experienced as stressful, since the participants would have to think twice about utterances made. For this reason, the aim of the project was made very clear to the participants. Furthermore, it was made clear that the project did not seek to judge them as individuals, nor rate how good or bad their performances were, and that information gained through the project would not be used in any setting at the university. All those participating in the project did so voluntarily, and they signed an agreement of informed consent (Boeije, 2009).

Validity. Finally, there was a concern about validity, which was also essentially an ethical question, since it involves how valid the interpretations are and their consequences (Messick, 1994). This question becomes especially ethical, since the researchers are a part of the TasS project, which makes it necessary to consider the following. How critical can the researchers be? How close can the researchers possibly be to asking certain types of questions? Furthermore, if the project were to propose the introduction of the intervention in future field practice, based on invalid conclusions, would this then be highly unethical? To prevent these ethical concerns, the TasS project teamed up with and involved national and international partners. These partners monitored and advised the TasS project throughout the whole process.

In these ways, the TasS project came to bear on ethical reflections while being transparent throughout the process

4 Results

The aim of this chapter is to present the main results from the four articles. A summary is first provided of the research findings from Articles 1 and 2, and subsequently of those from the detailed Articles 3 and 4.

4.1 *Articles 1 and 2: A comparison of INT and CSP during planning and reflection*

Two of the four articles, Articles 1 and 2 (Juhler, In review, 2016) (see Appendix F, G) threw light on the main research question (sub-section 3.1.3) by comparing the CSP and the INT (see reasons in section 3.1). This was done from the theoretical standpoint of PCK for science (see section 2.3). The Articles aimed to answer the following research questions.

Article 1: *"How does the use of Lesson Study combined with Content Representation affect preservice science teachers' potential to start developing Pedagogical Content Knowledge while planning a research lesson during field practice"*. Article 2: *"How does the use of Lesson Study in combination with Content Representation affect reflections during mentoring on a taught field practice lesson in science, judged from a theoretical perspective of PCK?"*

Article 1 specifically covered the steps 'comprehension' and 'transformation', while Article 2 specifically covered the steps 'reflection' and 'new comprehension', as described in Figure 2, p. 28, 'model of pedagogical reasoning and action': the articles thus together only cover parts of this process.

The aim of the articles was to provide evidence about the differences in focus between the two conditions that theoretically, as argued through section 2.4.1 and 2.4.3, might influence the PSTs' possibility of starting to develop PCK throughout the whole learning process. This was based on the view that PCK development happens through a recursive and non-linear process, as described in section 2.3.1. This means that a different focus during one step might in turn influence the other steps. If these differences can be connected to knowledge elements that have been shown by researchers to advance PCK development, then it could well be argued that these differences might influence the PSTs' possible PCK development.

To find out differences in focus between the two conditions, an unconstrained deductive content analysis (Elo & Kyngäs, 2008) was used to code data into 16 PCK categories. Then the results within each category were presented as percentages and used for comparison. One limitation of this method is that the results do not provide evidence about the quality of the differences found. Another is that the method cannot prove statistically significant effects but only claim theoretical generalization, as argued in section 3.4. This is due to the limited data material, the qualitative coding process, and the fact that there is no control for other factors. A full overview of all the research findings presented in Articles 1 and 2 is provided in Table 3, which can be found at the end of this section.

The results from the first article show that the main concern when planning a lesson during the CSP condition was on *C: Instructional strategies (69.3%)*, combined with concerns about *A: Curriculum (17%).* Within *C: Instructional strategies*, the PSTs first and foremost focused on *C3: Specific activities (30.6%)* and *C4: Organization (32.6%)*, and somewhat on *C2: Discussion of best representation (5.5%).* Within *A: Curriculum*, they primarily focused on *A3: The use of textbooks (9.8%)* and on *A2: National standards (5.1%)*. Therefore, only little focus was directed towards *B: Pupils' understanding (6.8%), and* D: *Assessment (6.9%)*. As a part of *B: Pupils' understanding*, the primary concern was on *B1: Prior knowledge (4.0%)* and on *B2: Motivators and difficulties (2.3%)*. The primary focus of *D: Assessments* was on *D3: Specific method (6.6%)*.

In contrast, the results from the INT condition show a much more uniformed focus on all of the four main categories: *A: Curriculum (13.8%)*, *B: Pupils' understanding (20.1%)*, *C: Instructional strategies (44.8%)* and *D: Assessment (21.3%)*. When comparing with the CSP, it can be seen that this more uniform focus is due to an increased focus on *D: Assessment* and *B: Pupils' understanding*, with less focus on *C: Instructional strategies*. Within *A: Curriculum*, the main concern was on *A1: Goals for instruction (9.2%)* and *A4: Scope and sequencing (3.3%)*, which is the opposite focus of the CSP. The main focus within *B: Pupils' understanding* was on *B2: Motivators and difficulties (13.2%)* and *B3: Misconceptions (4.5%)*, where the latter differs from CSP. C: The main concern of *Instructional strategies*, like that of the CSP, was on *C3: Specific activities (16.4%)* and *C4: Organization (17.2%)*.

However, the percentages are approximately half of those in the CSP. Additionally, both *C2: Discussion of best representation (5.7%)* and *C1: Pupil behaviour (5.5%)* are fairly represented. The main concern of *D: Assessment* was on *D3: Specific method (11.5%), D4: Hypothesis about pupil thought patterns (5.2%),* while only partly on *D1: Purposes and reasons (3.4%)* and *D2: Varied best strategies (1.3%)*. The latter three sub-categories were almost absent during the CSP.

The results from the second article show that the main concern when reflecting on a taught lesson during the CSP was on *C: Instructional strategies (92.0%).* Little concern was placed on *A: Curriculum (3.4%)*, *B: Pupils' understanding (0.4%)* and *D: Assessment (4.2%)*. Within *C: Instructional strategies*, the main concern was on *C4: Organizing and sequencing (56.8%)* and C3: *Specific activities (20.4%),* with less focus on *C2: Best representation (7.3)* and *C1: Pupil Behaviour (7.4%).* The main concern of *A: Curriculum* was on *A1: Goal for instruction (2.4%)*. Within *B: Pupils' understanding*, the only focus was on *B1: Prior knowledge (0.4%)*. Likewise, *D: Assessment*, only had one main concern, namely *D3: Specific assessment method (4.2%).*

When comparing the INT with the CSP, it was found that the PSTs, during the INT, had much less focus on *C: Instructional strategies (70%)*, even though it was still the main concern. Furthermore, it was found that the INT had much more focus on *D: Assessment (21.9%)*, approximately five times more than the CSP. The category *B: Pupils' understanding (3.8%)* was also increased, while *A: Curriculum (4.4%)* only showed a slight increment. Within *C: Instructional strategies*, the main concern was on *C2: Best representation (31.4%)* and *C3: Specific activities (19.8%)*, while partly on *C4: Organization and squeezing (12.9%)*, and little on *C1: Pupils' behaviour influencing instruction (5.8%)*. This sets this category apart from that of the CSP, where the main focus was on *C4: Organization and sequencing*. The main focus within *B: Pupils' understanding*, was on *B2: Motivators and difficulties (1.6%)* and *B3: Misconceptions (1.4%)*, whereas the only focus of the CSP was on *B1: Prior knowledge*. Within *D: Assessment*, the main focus was almost exclusively on *D3: Specific assessment method (21.6%)*, as with the CSP. Likewise, *A: Curriculum*, also had almost a single focus, *A1: Goals for instruction (3.6%)*, which was similar to the CSP.

The above results show that a main tendency during both conditions is a large focus on *C: Instructional strategies*; however, this focus is less during the INT than the CSP. This means that the other three categories *A: Curriculum, B: Pupils' understanding* and *D: Assessment* receive more focus during the INT than the CSP condition.

Table 3: Overview of research findings from Articles 1 and 2

	CSP Article 1	**INT Article 1**	**CSP Article 2**	**INT Article 2**
A: Curriculum	17.0%	13.8%	3.4%	4.4%
A1. Goals for instruction	1.7%	9.2%	2.4%	3.6%
A2. National standards	5.1%	1.3%	1.0%	0.1%
A3. Resources	9.8%	0.0%	0.0%	0.7%
A4. Sequencing of topics	0.4%	3.3%	0.0%	0.0%
B: Pupils' understandings	6.8%	20.1%	0.4%	3.8%
B1. Reflections on prior knowledge	4.0%	1.4%	0.4%	0.1%
B2. Motivators and difficulties	2.3%	13.2%	0.0%	1.6%
B3. Misconceptions	0.5%	4.5%	0.0%	1.4%
B4. Pupil's strategies	0.0%	1.1%	0.0%	0.7%
C: Instructional strategies	69.3%	44.8%	92.0%	70.0%
C1. Pupil behaviour	0.8%	5.5%	7.4%	5.8%
C2. Best representations	5.3%	5.7%	7.3%	31.4%
C3. Specific activities	30.6%	16.4%	20.4%	19.8%
C4. Organization	32.6%	17.2%	56.8%	12.9%
D: Assessment	6.9%	21.3%	4.2%	21.9%
D1. Purposes and reasons	0.0%	3.4%	0.0%	0.0%
D2. Best strategies	0.0%	1.3%	0.0%	0.2%
D3. Specific method	6.6%	11.5%	4.2%	21.6%
D4. Hypotheses	0.4%	5.2%	0.0%	0.0%

CSP: Current state of practice. **INT**: Intervention. **Article 1:** Planning. **Article 2**: Reflection. Percentages are calculated from each category's coverage of the full transcripts.

4.2 Articles 3 and 4: The teaching and assessment of a specific learning aim

Articles 3 and 4 (Juhler, In press; Juhler & Håland, 2016) (see Appendix H and I) illuminate the main research question (see 3.1.2) through detailed descriptions, based on findings from Articles 1 and 2. Article 3 specifically focuses on the teaching of a learning aim. Article 4 specifically focuses on the assessment of the specific learning aim, studied through Article 3. As such, the Articles aimed at answering the following research questions.

Article 3: *"How do student teachers of science plan, conduct and reflect on the teaching of a chosen learning aim when using the Lesson Study method in combination with the Content Representation tool?"*. Article 4: *"How do student teachers of science understand and implement assessment of and for learning, while using the Lesson Study method in combination with the Content Representation tool?"*.

In both cases the descriptions cover all six steps: 'comprehension', 'transformation', 'instruction', 'evaluation', 'reflection', and 'new comprehension', as depicted in Figure 2, p. 28, 'Model of pedagogical reasoning and action'. To answer the research question, a stepwise approach to content analysis (Boeije, 2009) was used. This approach uses a qualitative coding of data into the categories that the two articles specifically focus on. Subsequently, coded pieces that fitted together were used to create the descriptions provided in the articles. One limitation of this approach is that it only covers parts of the PCK construct.

The descriptions from the third Article show that the PSTs, during the planning of the research lesson, clearly stated subject-matter aims for the lesson. These were: 'Transfer of energy', 'Energy chains" and 'Energy is not created or disappearing'. In this respect, they had chosen three activities that might bring about this learning: 'Catapult firing', 'Newton's cradle' and 'Rubbing of hands'. However, no evidence was found providing insight into why these three activities were considered to be the best for teaching the subject-matter aim. Nor were there discussions about comparisons with possible alternative activities that the PSTs had considered using. However, they had considered, and were able to explain, how they thought the three activities would contribute to the pupils' learning of the subject-matter aim.

In connection with learning the concept 'Energy transfers', the PSTs expressed that the pupils had to understand the technical concepts used to describe the energy situation before and after an energy transfer had occurred. Furthermore, the pupils had to understand that energy was somehow transferred from one kind of energy to another. Through the combination of the chosen activities, and through emphasizing the technical concepts, the PSTs believed that learning would occur naturally.

During the teaching of the lesson, it was found that the PST who was teaching the lesson mentioned the technical concepts that the PSTs had planned to emphasize. However, when talking about the concept of energy, a discovery was that this happened without talking about the specific type of energy most of the time. Furthermore, the different types of concepts, e.g. what does ‘thermal energy’ really mean?, were not explained. Neither were there any explanations about how one type of energy is converted into another – simply that it was converted.

After the taught lesson and during the reflections, the generally expressed view among the PSTs seemed to be that the lesson was quite successful in terms of fulfilling the learning aim. However, the PSTs did express concerns about whether some of the pupils had understood the technical concepts. In this respect, they thought that talking in more detail, knowing what a good/right answer from a pupil might look like, and knowing what a correct definition might be, would have helped.

The results from the fourth article illustrate that the PSTs, during the planning of the research lesson, expressed that they could use the pupils’ utterances and writing to assess their learning. To do so, they had developed two assessment tools: A hypothesis form covering the three activities, and an observational manual. The expressed main aim of the hypothesis form was to get the pupils to write their understanding down before the experiment – formulating a hypothesis about what was happening and, after the experiment, explaining what they saw in addition to writing the correct explanation together with teacher. The observational manual expressed which aspects of the research lesson the PSTs who were not teaching the lesson should focus on in the classroom. Specifically, these were whether the pupils seemed to have understood the covered content – why/why not, or whether the focus was on the activity itself.

During the conversations, the mentor teacher tried several times to get the PSTs to be explicit about which written/spoken evidence the pupils could hypothetically express, confirming or disconfirming the pupils’ understanding. However, the PSTs either avoided these questions or expressed themselves vaguely. In the end, the mentor teacher asked them to make an explicit list, so specific that the PSTs should be able to use it to tick off items during the research lesson.

During the teaching of the research lesson, an observation was that the PSTs walked around in the classroom collecting evidence and using the tools described above. While details about these observations were not collected, it could be observed that they took notes and followed the pupils closely. The one PST who was teaching asked many questions aimed at getting the pupils to verbalize some of their theories. The PST who was teaching the lesson responded to the pupils' answers, primarily through giving a recap, giving the right answer, answering 'yes/no', or by not responding but instead moving on with the lesson. Only in a few instances did the PST who was teaching ask the pupils to be more specific, or challenge the pupils to explain the reasoning behind their thoughts.

During the reflections after the taught lesson, three out of the four PSTs expressed that the lesson was quite successful in terms of fulfilling the learning aim. This was based on observations showing that the chosen activities had engaged the pupils, resulting in them becoming focused and interested, which led the PSTs to believe that the pupils had understood the learning aim. The three PSTs did not mention or use the hypothesis form or other collected observations as evidence for their claim. However, one of the PSTs was sceptical. This PST commented that the pupils seemed to have had a hard time understanding the connection between the activities and the learning aim. This was based on observations showing that the pupils did not use the related terms and concepts that they were supposed to learn about. This view was supported by the mentor teacher. The one PST concluded, contrary to the others, that the pupils had properly acquired knowledge as a set of separate pieces of information.

Overall, the above research findings show that the PSTs to some degree focus on and discuss the researched areas in depth when planning, conducting and reflecting on teaching. A discussion of these findings, and how they fit together with the research findings presented in Articles 1 and 2, is the aim of the following chapter.

5 Discussion

In light of the main research question (section 1.2 and sub-section 3.1.2), this chapter first discusses the results presented through the four articles (Chapter 4) and relates it to the presented theory and research (Chapters 1 and 2). Second, three overarching perspectives are discussed that relate to the implementation of LS into teacher education. With regard to all of the above, a main objective is to critically discuss how this extended abstract has contributed to the research field. Third, limitations introduced by the research choices are addressed. Finally, the results are then used to draw overall conclusions and to point to future research that is needed.

In light of the cognitive and social/socio-cultural constructivist theory presented in section 2.2, the present chapter needs to be understood as the researcher's own constructed understanding, as an extension of known knowledge, and not as the absolute truth. Furthermore, it needs to be seen as part of an active research agenda that seeks to study PSTs' PCK for teaching science as this develops through social interaction during field practice, and as it unfolds within the cultural context of science teacher education (Chapters 1 and 2).

5.1 *PSTs' possible PCK development when using LS in combination with CoRe*

This section discusses the main research question: "*How does the use of Lesson Study combined with Content Representation affect pre-service science teachers' potential to start developing Pedagogical Content Knowledge during field practice in teacher education?*" First, it considers this question in light of the research findings presented in Articles 1 and 2, and subsequently in light of Articles 3 and 4. Finally, the findings from all the four articles are combined and compared to those of the CSP in order to provide a greater understanding of possible PCK development throughout the whole cycle of pedagogical reasoning and action (Figure 2, p. 28).

5.1.1 Articles 1 and 2: Comparison of CSP and INT

Articles 1 and 2 have tried to answer how the INT affected the PSTs' potential to start developing PCK compared to that in the CSP. Specifically, the articles looked into differences in focus in PCK categories during either the planning or the reflection steps of the process of pedagogical reasoning and action (see Figure 2, p. 28). To start the discussion, a description is provided of the findings relating to CSP concerns. From this, it will then be shown how the INT changed the PSTs' focus in ways that, as described in Chapter 2, theoretically lead to a greater potential to start developing PCK during the researched stages.

The main CSP concern when planning and reflecting during field practice, through Articles 1 and 2, was shown to be about C: *Instructional strategies*, averaging 80.6%, combined with some concerns about *A: Curriculum*, averaging 10.2%. This means that very little focus was attached to understanding the pupils' perspectives during the CSP, and to the assessment of whether or not, as well as how, the pupils had understood the learning aims. These findings are consistent with prior research which shows that PSTs have a focus on general management and survival concerns during field practice (Bradbury & Koballa, 2007; Gess-Newsome & Lederman, 1999; Helgevold et al., 2015; Kagan, 1992; Loughran et al., 2008; Weiland et al., 2010). The comparability lends further credence to the findings in the present study.

Judged from the theoretical perspective of PCK, the planning and reflection during the CSP condition therefore showed a lack of focus on crucial theoretical elements, such as pupil's perspectives and assessment, that PSTs need to focus on in order to combine theory and practice (Gess-Newsome & Lederman, 1999; Loughran et al., 2008), which indicates that little coherence between the two exists, as argued in section 2.1. Furthermore, as argued in sub-section 2.3.3, this may also mean that the PSTs' PCK development was prohibited, since PCK growth relies on the development of knowledge, both within and between the different PCK components (Magnusson et al., 1999).

The main findings from the INT, in contrast, show a much more uniformed focus on all of the PCK categories when compared with the CSP. This was the case, even though it was less prominent during the reflection stage. This difference occurred since the PSTs, during the INT, had much less focus on C:

Instructional strategies and more focus on *B: Pupil understanding* and *D: Assessment*. A more uniform focus may have given the PSTs a better opportunity to start connecting the different PCK elements during the INT, thus creating coherency, which is necessary for PCK development, as described in sub-section 2.3.3. This is opposed to the CSP, where the focus was only on some elements and which thereby did not allow for a development of a coherent understanding. In this way, LS and CoRe may also have promoted the PSTs' possibility to start connecting theory and practice, which is also a finding of previous research (Cajkler, Wood, Norton, & Pedder, 2013; Carrier, 2011; M. Fernandez, 2005). A reason for this change could be that the collaborative work carried out through LS counteracted the PSTs and the mentoring teacher adhering to the culture of the practice school, which has previously mostly been found to be the case (Sundli, 2001, 2007; Tobin et al., 1994) (see sub-section 2.1.3).

When examining the sub-categories, a specific finding was that the PSTs focused less on: *A2: National standards*, *A3: Textbooks*, *B1: Prior knowledge*, *C3: Specific activities* and *C4: Organization*. These focus areas are all related to basic teaching concerns. This arguably shows that the PSTs were less focused on questions about general management and survival concerns during the INT, which is the typical tendency (Burn et al., 2000; Gess-Newsome & Lederman, 1999; Levin et al., 2009; Loughran et al., 2008; Weiland et al., 2010).

On the other hand, the PSTs focused more on: *A1: Goals*, *A4: Scope and sequencing*, *B2: Motivation and difficulties*, *B3: Misconceptions*, *B4: Pupils' strategies*, *C2: Best representation*, *C1: Pupils' behaviour, D1: Purpose*, *D2: Best strategies*, *D3: Specific method* and *D4: Hypothesis*. All of these focus areas cover concerns about the pupils to some degree. Therefore, these findings give credence to prior claims that both LS and CoRe can lead to the PSTs adapting a more learner-centred approach to teaching (C. Fernandez & Yoshida, 2004; Lewis, Perry, Friedkin, & Roth, 2012; Nilsson & Loughran, 2012b; Perry & Lewis, 2009), which is contrary to what has been found in prior practice (Burn et al., 2000; Gess-Newsome & Lederman, 1999; Levin et al., 2009; Loughran et al., 2008; Weiland et al., 2010).

When comparing the categories receiving less focus with those receiving more, as discussed above, it can furthermore be found that the categories receiving more focus, to a larger degree, cover theoretical aspects from both pedagogy and subject content taught during teacher education. For example, *B2: Motivation and difficulties* and *B4: Pupils' strategies*, *D1: Purpose*, *D2: Best strategies*, *D3: Specific method*, primarily rely on theoretical elements from pedagogy. *A1: Goals, A4: Scope and sequencing, B3: Misconceptions*, *C2: Best representation* and *D4: Hypothesis*, primarily rely on theoretical elements from the subject physics. Of course, this is a simplification, since most of the elements draw on both pedagogical and subject-matter knowledge (SMK), which is further combined with practice experience. This altered focus implies that theory from teacher education was given more attention during the INT than the CSP. This is consistent with prior research findings claiming that CoRe (Loughran et al., 2008) and LS (Cajkler et al., 2013; Carrier, 2011; M. Fernandez, 2005) can give PSTs a better opportunity to start bridging the theory-practice divide (Gess-Newsome & Lederman, 1999; Loughran et al., 2008). Furthermore, it indicates that the planning and reflection on lessons, as a consequence of the INT, potentially changed the practice experience. It accomplished this in ways that, compared with the CSP, are theoretically connected to teaching modes that seem to increase pupils' learning outcomes (Canrinus et al., 2015), as argued in section 2.1.

The four differences discussed above, when judged from the theoretical perspective of PCK as defined in sub-section 2.3.3, imply that the INT affected the PSTs' potential to start developing PCK during the planning and reflection step in four positive ways. First, it gave the PSTs a more even focus on all PCK categories. Second, it gave the PSTs less focus on general management and basic survival concerns. Thirdly, it gave the PSTs more focus on the pupils and their learning. Finally, it made the PSTs focus more on theoretical elements presented during teacher education. However, since Articles 1 and 2 cannot throw light on the quality of the differences that were found (see section 5.3 for reasons), it may well be such that the discovered differences only occurred because the PSTs were guided in this way. If such was the case, it is possible that the PSTs did not focus on these aspects in a meaningful manner. This is the main reason why Articles 3 and 4 focus on the quality and reasoning behind two of the discovered differences that indicate a positive outcome on PCK development.

5.1.2 Articles 3 and 4: Teaching and assessing a subject-matter aim

Articles 3 and 4 have looked into the research questions about how the PSTs planned, conducted and reflected on the teaching of a chosen learning aim and on the assessment of that chosen learning aim when using the LS method in combination with the CoRe tool. In light of these descriptions, the present subsection will discuss how these research findings from Articles 3 and 4 inform the question of the quality of two important differences found and discussed in Articles 1 and 2. This will happen through individual discussions of the three steps of planning, teaching and reflection, followed by an overall comparison and discussion of these three steps.

The main findings from planning show that the PSTs put a good deal of work into thinking about and defining subject-matter learning aims and assessment of the learning aims.

Article 3 specifically shows that the PSTs defined subject-matter aims, including explanations about what exactly the pupils were expected to understand. The PSTs also introduced three specific activities that they believed would lead to this learning, as well as some explanations of how it would do so. These activities were partly designed to enable the pupils to voice their understandings, which suggests that the activities were not used to give the teachers control over the learners, as has previously been found to be the case (Black & Harrison, 2006).

The findings from Article 4 specifically show that the PSTs themselves developed two assessment means which, through pupils' written and spoken responses, were intended to be used to collect necessary assessment evidence. Of these, the developed hypothesis form especially shows that the PSTs did not direct their attention only towards low-level aims, such as grading and recall, which is a typically found tendency (Black & Wiliam, 1998; Anne Hume & Coll, 2009; Radnor, 1994; Shepard, 2000). Both findings show a positive contrast to that of earlier praxis (Appleton, 2006; Bradbury & Koballa, 2007).

However, both articles also report that the PSTs' understanding of the two focus areas might not be as deep and linked as it appears, which is arguably an effect of the PSTs' status as learners. Article 3 specifically shows that the PSTs did not discuss why the three chosen activities were the most suitable to fulfil the subject-matter aims, nor did they discuss alternative activities. This indicates a weak link between the subject-matter aims and the chosen activities. Furthermore, the PSTs only managed to describe learning as little more than being able to reproduce and use the specific concepts when writing and talking about the activities, even though the hypothesis form indicated that they had a more complex understanding than this. The above two findings may be a consequence of the PSTs possessing too little SMK and perpetuating a naive idea about learning. Both of these problems are also findings in previous research (Gess-Newsome & Lederman, 1999; Loughran et al., 2008).

Article 4 specifically shows that the PSTs did not manage to be explicit about which written/spoken evidence the pupils could hypothetically express and which could lead to confirmation or disconfirmation of the pupils' understanding. Therefore, it is questionable whether the PSTs managed to connect the developed tools specifically to how the gathered evidence should be used to assess pupil learning. The problem of linkage in this respect has previously been reported (Gess-Newsome & Lederman, 1999).

The above-found weaknesses indicate that the PSTs did not manage to go into great enough depth during the *kyozaikenkyu* (Key feature 1.b of the LS process, p. 44-45), since these concerns should have been considered there. This is also a previously reported problem (Doig et al., 2011; C. Fernandez et al., 2003). Furthermore, it also indicates that the PSTs did not manage to connect together the different pedagogical prompts that need to be considered when filling in the CoRe (Figure 7, p. 48).

The main findings from the taught research lesson in both articles reveal a situation in which the PSTs' intentions, expressed during the planning stage, became somewhat problematic when put into practice.

Through Article 3, it was specifically shown that the one PST who was teaching focused on the teaching of the subject-matter aim. However, this was done in a rather imprecise manner, i.e. not specifying the type of energy, not explaining what the different technical concepts meant, or how one energy type was converted into another. As such, the PSTs taught contrary to their expressed intentions, which stated the need to emphasize the technical concepts. This finding can likely be explained in two ways. First, the PSTs demonstrated a weak understanding of what learning entails. Second, the PSTs demonstrated a weak understanding of the link between the learning aim and the activity. Both problems have been reported in prior research (Gess-Newsome & Lederman, 1999; Loughran et al., 2008).

Article 4 showed that the PST who taught the lesson did not use questions in a deliberate manner to gather the necessary assessment information. Instead, the teacher primarily responded to pupils' answers with a recap, providing the correct answer, answering yes/no, or by not responding at all and simply moving on with the lesson. Thus, it may seem that getting the pupils to voice their ideas, in addition to the correctness of the answer, was more important than probing into the pupils' understanding. One possible reason for this is that the PSTs, during the planning stage, did not manage to anticipate what they could expect in the way of pupils' responses. Another reason is that they did not discuss in detail how the hypothesis form, in conjunction with the activities, should be used to elicit the required information. The result was that the PSTs failed to explore the opportunities provided by the conversations to dig deeper into the pupils' understanding, and thus did not gather the necessary evidence for assessment. These problems have also been reported in prior research (Campbell & Evans, 2000; Morrison & Lederman, 2003). This suggests that the PSTs did not manage to keep the research lens when teaching, a problem also previously reported (C. Fernandez et al., 2003; Murata, 2011)

The findings presented in both articles show the planning to be somewhat at odds with actual classroom practice, as reported in previous research (Van Driel et al., 1998). This finding might hinge on the research finding that the PSTs, through the theoretical subjects taught in teacher education, are not shown how these can be transformed into action (Sundli, 2007). Furthermore, both findings are contrary to the intentions of both the LS method (C. Fernandez & Yoshida, 2004) and the CoRe form (Loughran et al., 2012), since these both stress the connections between measures, deep understanding of subject-matter, and the collection of evidence as a basis for assessment. Thus, these findings support the prior argument that the PSTs did not enter into great enough depth during the *kyozaikenkyu* (Key feature 1.b of the LS process, p. 44-45).

The main findings from the reflection stage show that the PSTs managed to address the weaknesses discussed above to some extent.

Article 3 shows that the PSTs, when reflecting on the taught research lesson, were able to pinpoint many of the shortcomings that occurred during the planning phase, which is contrary to what prior research has found (Bradbury & Koballa, 2007). Specifically, the PSTs were concerned with the teaching of the technical concepts, which they thought should have been taught in much more detail. In this regard, they expressed that it would have especially helped if they had discussed during the planning phase what a correct pupil answer might look like, and what a correct definition might be. This shows that the PSTs themselves acknowledged that they needed to obtain deeper knowledge of the subject-matter aim during the planning phase, and its connection with the specific teaching activity. This is a vital part of both the *kyozaikenkyu* (Key feature 1.b of the LS process, p. 44-45) and the CoRe (p. 48).

Article 4 shows that three out of four PSTs used classroom management, pedagogical concerns and unsubstantiated gut feelings when proclaiming that the lesson had gone well, a finding consistent with prior research (C. Fernandez et al., 2003). When claiming this, they did not mention or use the hypothesis form, or any other collected observations, as evidence. A reason for this could be that, during the planning step, they were unable to be explicit about which written/spoken evidence they could expect from the pupils, resulting in them not being able to gather the necessary assessment information, which is a problem also discovered in previous research (Morrison & Lederman, 2003). Additionally, the PST who was teaching did not use posed questions to gather necessary assessment information. This arguably shows that these PSTs had lost their research lens, as also reported in prior research (C. Fernandez et al., 2003; Murata, 2011). They thus assessed in a manner contrary to the intentions of both the LS method (C. Fernandez & Yoshida, 2004) and the CoRe form (Loughran et al., 2012). However, the fourth PST managed to use some evidence as a basis for assessing the lesson, which gave this PST a more critical view of the pupils' learning. This arguably shows that this PST had a different understanding from the others, i.e. of what it might mean to have learned something, which might be an influence of the use of LS (C. Fernandez & Yoshida, 2004) and the CoRe (Loughran et al., 2012). In this regard, it is interesting to note that this understanding did not seem to change as a consequence of the group discussions. This might indicate that this PST's personal beliefs and understanding, when challenged in a social context, were resistant to change. If this was the case, it is a finding consistent with prior research (Appleton & Asoko, 1996). Regardless of whether this was the case or not, it indicates the dynamics between personal cognition and socially constructed knowledge, as argued in section 2.1.

When considering all three steps according to the 'model of pedagogical reasoning and action' (Figure 2, p. 28), the following pattern emerges. During the 'Comprehension' and 'Transformation' step, where the PSTs reflected on action, a fair understanding of the different PCK components and their connections was expressed. During the 'Instruction' and 'Evaluation' step, when having to enact their knowledge, it was however found that the transformation of theory into action was somewhat problematic. However, during the 'Reflection' and 'New comprehension' step, again reflection on action, the PSTs were able to provide reasoned reflections on the shortcomings in understandings of the different PCK components. This was more prominent for the teaching of the learning aim than for assessment. Considering these aspects during reflection would arguably give the PSTs a basis from which to reconsider these aspects when planning and teaching the revised lesson as part of LS (C. Fernandez & Yoshida, 2004), in turn promoting their possibility to develop PCK.

5.1.3 Articles 1-4: Combining the results

This section seeks to combine the results reported from the four articles as related to the whole process of pedagogical reasoning and action (Figure 2, p. 28) in order to inform the overarching research question.

The results from Articles 1 and 2 indicate that the PSTs, during the CSP planning and reflection steps, mainly focused on concerns related to general management and survival. This indicates that the PSTs' PCK development must have been prohibited, since PCK growth relies on the development of knowledge, both within and between all of the different PCK components (Magnusson et al., 1999) as described in sub-section 2.3.3. In contrast, the PSTs focused more evenly on all PCK categories during the INT planning and reflection steps, which would arguably provide them with the chance to start reflecting on all of the different PCK components and how these influence each other. As argued, this would only be possible to a very small degree during the CSP. This indicates that the INT affected the PSTs' potential to start developing Pedagogical Content Knowledge in a positive manner.

The degree to which this potential was affected in a positive manner was shown in **Articles 3 and 4**. Here it was shown that the PSTs engaged with the teaching of a subject-matter aim and its assessment in a somewhat meaningful manner, two aspects which typically receive little attention (Gess-Newsome & Lederman, 1999; Loughran et al., 2008). This indicates that the PSTs' different focus during the INT was not simply because they were directed in this way by the LS method (C. Fernandez & Yoshida, 2004) or the CoRe form (Loughran et al., 2012), but that it indeed contained some level of quality. This lends credence to the increased potential to develop PCK, as claimed theoretically through Articles 1 and 2. This is especially so, since these important differences were found even though the participants were in their second year during the INT, while in their third year during the CSP. This arguably gives the latter group an advantage, as described in 3.2.5. However, the discussions additionally showed that the PSTs did not make profound connections between or gained sufficient knowledge within the different PCK components, which is a hallmark of profound knowledge as described in sub-section 2.3.3. Yet, it was indicated that the PSTs, through their way of reflecting, had the potential to rectify these aspects during a subsequent LS round. If so, they might start to develop PCK at this stage.

Two possible reasons behind the lack of profoundness were identified. One was the lack of engagement with the *kyozaikenkyu*, which is the detailed planning stage of the LS process (Key feature 1. b, p. 25). The other was that the PSTs seemed to have lost their research lens throughout the LS process. Research shows that when these two problems are prominent, PSTs do not get to understand LS as a story with a connected beginning, middle and end, in which deep conceptual meaning is found in the complex connections between the parts. Without gaining this understanding, only superficial knowledge will develop (Stigler & Hiebert, 1999; Yoshida & Jackson, 2011). A reason for this might be that the PSTs struggled with the complexity level of the tasks involved in planning, conducting and reflecting on a lesson and, as a consequence, might have filtered out details and connections, as previously found (Kagan, 1992).

This indicates that the field practice experience during the INT was less able to promote the PSTs' potential to develop PCK than what was theoretically argued through the discussions of the findings from Articles 1 and 2. However, when considering this, it is important to be reflective about the fact that the LS method and the CoRe place a high cognitive load on the PSTs, in that they need to consider both the individual PCK components and their connections (C. Fernandez & Yoshida, 2004; Loughran et al., 2012). Therefore, these results need to be seen in the light of the abilities that the PSTs possess at this educational stage of their development, which is that of learners, and that PCK as a construct represents what an expert teacher is able to do. It cannot thereby be expected that they possess deeply rooted knowledge about the different PCK components or their connections. However, what can be hoped for is that the PSTs start to be reflective about the different PCK components and how they are connected, which is arguably the case in the present research.

In light of the discussions in this section, it therefore seems reasonable to suggest that the INT did influence the PSTs potential to start developing PCK in a positive direction when compared to the CSP situation. This was done by making the PSTs focus more equally on all the different PCK components and how they relate to each other, together with the findings that indicated that this happened in a somewhat meaningful manner. Furthermore, it is substantiated by the fact that the PSTs were able to pinpoint important shortcomings during the first round of planning, teaching and reflecting, and which could be focused on in a deeper and more connected manner during the second round. However, it was also shown that the PSTs had only started to unravel surface aspects within the complex area of PCK at this stage, thus failing to understand the depth and interconnectedness of the required components of PCK, according to section 2.3.3. The reasons for this are possibly connected to the lack of profound engagement with the *kyozaikenkyu* (Key feature 1.b of the LS process, p. 25), and in keeping their research lens throughout the LS process. Both aspects are arguably connected to their status as learners and the challenges involved in learning how to teach (see section 2.1).

5.2 Overarching perspectives

In this section, three overarching perspectives are discussed. First, the CoRe's specific contribution as a scaffolding tool when PSTs use LS during field practice is discussed. Second, a discussion follows of how constructivist theory adds to our understanding of the way professional development happens when using LS and the CoRe during field practice. Finally, there is a discussion of the challenge of helping PSTs engage profoundly with the LS method during field practice, as related to the ongoing discussions within the field.

5.2.1 The CoRe's specific contribution to the INT findings

As argued in sub-sections 2.4.2 and 2.4.3, the CoRe form was combined with LS in a novel attempt to scaffold the challenging task of helping newcomers to engage effectively with the innovative method of LS during field practice. This warrants a discussion of the CoRe's specific contribution, even if the study design does not allow for the effects of the LS and the CoRe to be fully distinguished and the fact that the LS and CoRe aims overlap. This discussion is furthermore warranted since other researchers who compared the subjects studied in TasS found that the science discipline distinguished itself positively (Bjuland, Helgevold, & Munthe, 2015; Helgevold, Næsheim-Bjørkvik, & Østrem, 2013).

The discussions of the CoRe's specific contribution will be based on evidence from Articles 1–4, the description of the data collection steps (sub-section 3.2.3), and research findings from the other TasS researchers. What will be argued is that the CoRe form seemed to have scaffolded the LS process to some extent. Specifically, it will be shown that the CoRe form seemed to have helped the PSTs and the mentor teacher to focus on subject-matter aims in greater detail, in addition to focusing on the pupils' understanding and assessment.

From sub-section 3.2.3, it can be seen that the PSTs filled in the CoRe form prior to the pre-mentoring sessions and brought the form to the mentoring sessions. The aim of the CoRe, as described, was to get the PSTs and the mentor teacher to focus especially on the connection between the research aim (key element 1.a), investigation (key element 1.b), and how these were linked to the choices made during planning (key element 1.c) (see Figure 6, p. 44-45).

The results from Article 3 specifically show that they used the 'big ideas' from the CoRe to discuss what they wanted the pupils to understand, and which activities should be used to reach this goal. These findings are also reflected in Articles 1 and 2, which reveal a greater focus on *A1: Goals for instruction* and *C2: Best representation*. Furthermore, during the reflection step, the PSTs identified two problems that can be connected to the CoRe. First, they should have better considered what a correct answer might look like, and second, what a correct definition might be.

Article 4 specifically shows that the PSTs discussed assessment of the learning aim and the pupils' possible responses. These findings are also reflected in Articles 1 and 2, which show an overall increment within the main category *D: Assessment* of 16.1%, which includes all sub-components compared to the CSP. This concern is specifically connected to the last pedagogical prompt within the CoRe form.

As such, the CoRe form's 'big ideas', as connected to the pedagogical prompts, seem to have influenced the PSTs' and the mentors' ways of thinking and discussing throughout the intervention. This arguably shows that the CoRe, combined with LS, helped the PSTs to engage more profoundly with the LS process than what has previously been found (Bocala, 2015; Doig et al., 2011; Fujii, 2016; Yoshida & Jackson, 2011). Specifically, it helped the PSTs to focus on subject-matter aims, the pupils' understanding, and assessment. This was arguably a contributing factor to why the mentor teachers and the PSTs were found to focus more on theoretical perspectives taught during teacher education, which has typically not been the case (Sundli, 2001, 2007; Tobin et al., 1994).

Two research findings from the TasS-project may point in the same direction. Helgevold, Næsheim-Bjørkvik and Østrem (2013) compared the four subject areas studied in the TasS project: Mathematics, English, Physical Education, and Science. They did so by studying mentoring conversations during internship in both the CSP and the INT condition, and analysed these through 'thin descriptions'. They found that, of all the subjects during the INT, science had a greater focus on both the pupils and the teaching of subject-matter. Bjuland et al. (2015) built on these results by analysing INT mentoring sessions in mathematics and science through a theoretical framework that highlighted pupils' learning (Bransford et al., 2004). In this research, they found that science had a much clearer focus than mathematics on the teaching of subject content, as related to the pupils and their understanding. They provided several explanations as to why this was the case. However, they did not consider the possible positive effects that the CoRe might have had. Since we know from sub-section 2.4.3 that CoRe especially helps the PSTs to focus on the subject-matter aim and the pupils' learning, and that science was the only TasS subject-area using the CoRe, it seems reasonable to suggest that some of the differences discovered were a consequence of using the CoRe in combination with LS.

When combining the above arguments, it seems reasonable to assume that the CoRe, to some degree, did have the intended effect claimed in sub-section 2.4.3. The CoRe thus helped the PSTs to define important integrated dimensions of expertise in science teaching. This means that the CoRe, as a conceptual tool, can to some extent help to start co-construct the knowledge needed by PSTs to become efficient teachers when using the LS method.

5.2.2 Theoretical view of the dynamics of professional development through LS and CoRe

As argued in section 2.2, professional development should be focused on both cognitive and social/socio-cultural constructivist theory. This sub-section seeks to investigate the research findings from these two views. Specifically, it will look into the dynamics between the two aspects, and how these may promote the PSTs' professional development. In light of this, it will be argued that the TPK&S model (Figure 5, p. 37) has increased explanatory power compared to the model 'Components of PCK for science teaching' (Figure 4, p. 33).

Through the discussions and arguments presented in section 5.1, it can be seen that the LS and CoRe provided the PSTs with specific input during the INT, which included opportunities to enact certain instructional strategies and to reflect, both individually and collectively, on their experiences, as argued by Van Driel and Berry (2012). Through these experiences, the individuals within the group were found to voice and discuss their personally-held understandings which, compared to normal practice, would provide them with a better opportunity to start change and to develop their understandings. This is the case since teachers' understandings are typically held tacitly (Edwards, 1997a; Gess-Newsome, 1999; Korthagen & Kessels, 1999; Loughran et al., 2012, 2000) and therefore, to a lesser degree, are challenged through peer discussions. Consequently, they are difficult to change (Appleton & Asoko, 1996; Louie et al., 2002). Following the discussions of these individually-held cognitive understandings, a somewhat shared understanding for teaching was developed, implemented and reflected on, as argued through social constructive theory. This mechanism has previously been argued by Lewis and Hurd (2011). However, the case of the PST who argued differently when assessing the learning outcome arguably shows that individual cognition still played an important role in the PSTs' understanding of teaching, as argued by Ertmer and Newby (1993) and Kaufhold (2002).

With regard to the social construction of knowledge, the CoRe form, as debated above, was largely found to influence the focus of these discussions. The same can be said about the content of the LS steps described in Figure 6, p. 44-45, which were given to the participants as a handbook (Munthe et al., 2015). Therefore, one may argue that the CoRe form and the LS handbook acted as cultural tools that changed the participants' focus during field practice (Säljö, 2001). They achieved this by serving as a common framework for both the PSTs and mentor teachers on how to plan, conduct and reflect throughout the LS cycle. The focused discussions that seemed to develop as a consequence of the use of LS and CoRe, in which the mentor teachers and PSTs established more collaborative partnerships, may be the reason why several previously reported problems within the cognitive domain were discovered to a lesser degree. This applies to teaching with transmissive beliefs, the perpetuation of naive ideas, the lack of sufficient SMK, and the teaching of knowledge structured in incoherent and unconnected ways (Gess-Newsome & Lederman, 1999; Loughran et al., 2008; Louie et al., 2002). Furthermore, it may explain why the PSTs did not become socialized by the mentors into traditional models of teaching, which is often the case (Brouwer & Korthagen, 2005).

In combination, the above discussions, together with section 5.1., indicate that LS and the CoRe seemed to provide the PSTs with more efficient ways of thinking about theory, practice, and their connections, as previously argued (Dotger, 2015; Murata, 2011). Consequently, it seems that the PSTs started using teaching modes that were more likely to increase pupil outcomes, as described by Canrinus et al. (2015), than what is usual during regular field practice (Gess-Newsome & Lederman, 1999; Loughran et al., 2008). It thus appears that the INT has the potential to contribute to real teacher change, i.e. towards becoming efficient teachers, something which has previously been found difficult to achieve (e.g. Lewis et al., 2009). These changes arguably happened through the social creation of a culture in which planning, conducting and reflection on teaching, were carried out with greater depth, with more coherence, and with an increased focus on theory gained through teacher education, than what has previously been found (e.g. Kagan, 1992; Weiland et al., 2010). The INT therefore appears to have aligned closer with teachers' professional practice, as explained in Chapters 1 and 2.

These perspectives indicate that the social setting of LS and CoRe combined may be able to co-construct the PSTs' learning in a way that provides them with an increased opportunity to start developing their PCK for science compared to what regular field placement provides (Dudley, 2013; C. Fernandez, 2005). Furthermore, the discussed dynamics indicate that the TPK&S model (Gess-Newsome, 2015, Figure 5, p.37) has more explanatory power than the model of Magnusson et al. (1999, Figure 4, p. 33). This is the case since the former model considers PCK as both personally held and also developed in a social/socio-cultural context, whereas the latter model primarily considers PCK as a personal construct, without considering how it is developed (Gess-Newsome, 2015).

5.2.3 Contribution to an ongoing discussion about implementing LS into teacher education

This study, as opposed to many other LS studies, uses a theoretical lens for the aims of professional development (Lewis et al., 2009), as happening through planning, teaching and reflection on a lesson, in order to critically examine the possible impact of LS on PSTs' PCK development. In addition, it uses the CoRe as a novel tool to scaffold the process. All of these elements play a part in the ongoing discussion about the implementation of LS into teacher education field practice. The following will discuss how the present research adds to these ongoing discussions.

Recent years have witnessed an increase in the number of studies on the use of LS as a part of teacher education. In this regard, scholars such as Bjuland and

Mosvold (2015) and Cajkler et al. (2013) argue that LS studies largely report success stories (e.g. Dudley, 2013; Ikzan, Zakaria, & Daud, 2014), even when examining the 'messiness' of learning through LS (e.g. Parks, 2008). At the same time, it has also been reported that longitudinal and comprehensive studies of LS on the whole do not exist (Lewis & Perry, 2014; Yoshida, 2012). Most studies that do exist have not engaged in a full plan-teach-observe-evaluate and re-teach cycle and, furthermore, they show great variety in methods, thereby making comparisons hard to draw (Cajkler et al., 2013). This argument is not meant to challenge the possible effects of LS, which have generally been established (e.g. Gersten, Taylor, Rolfhus, & Newman-Gonchar, 2014), but to underline that too few studies use critical lenses to examine the impact of LS (Lewis et al., 2009). Consequently, discussions about challenges are few (e.g. Bjuland & Mosvold, 2015; Parks, 2008), which means that proper judgment about quality is neglected. Instead, most studies normatively prescribe or describe the effects of LS (Norwich & Ylonen, 2013).

In this respect, the present study provides new knowledge that specifically shows that a critical view, gained through the utilization of PCK in combination with different methods that have enabled the quality of the intervention to be assessed, may be especially important when regarding the feasibility of implementing LS in teacher education. For instance, the present study's conclusions would have been much more positive if only judged through Articles 1 and 2, which only looked at differences in focus, and which were not nuanced by the reported findings on quality presented in Articles 3 and 4. The present study thus partly re-affirms somewhat known knowledge, such as the finding that LS can make PSTs focus more on pupils' learning (e.g. Norwich & Ylonen, 2013), and may help to combine theory and practice (Cajkler et al., 2013; Carrier, 2011; M. Fernandez, 2005). It also partly presents new knowledge through questioning the profoundness of engagement and, in turn, of the knowledge gained by PSTs during field practice through using LS combined with the CoRe. It does so, even though it was argued that the scaffolding tool CoRe has contributed positively in this respect.

The challenge of profound engagement with LS (described by, Doig et al., 2011; C. Fernandez et al., 2003; Murata, 2011; Yoshida & Jackson, 2011) is especially important since Lewis et al. (2009) question the efficiency of LS compared to other professional development measures that may achieve more in less time, and since teacher education only lasts 3-4 years (Sickel et al., 2015).

In this regard, Bjuland and Mosvold (2015), through a challenging case of LS implementation into field practice, argue for the importance of making the PSTs focus on pupil learning, making this visible, and gathering evidence through structured observations. These findings are closely aligned with the arguments presented by Doig et al. (2011), and by Fuji (2016), who state that the collaborative work that goes into creating the lesson plan is largely under-appreciated by non-Japanese adopters of LS. The present study adds to this knowledge by suggesting that scaffolding tools, such as the CoRe, can help in this respect. However, it also begs the question about how much engagement PSTs can possible reach when they are new to the LS method and also to teaching the subject in general. This question becomes especially relevant since it has been reported that educated teachers also struggle to make the LS method powerful, even when helped out by expert Japanese LS teachers (C. Fernandez et al., 2003). This may illustrate that the development of a profound understanding as a consequence of participating in LS is something that requires time (e.g. Bocala, 2015). This is quite feasible when considering the complexity of the task at hand (see descriptions by C. Fernandez & Yoshida, 2004; Loughran et al., 2012). Therefore, teachers in general, but arguably PSTs in particular, need time to develop the cognitive schematics and connections that would enable them to handle the complexity of LS, as described in section 2.1. The time perspective of development, however, is not covered by the present study, since it only depicts the first round of planning, teaching and reflection.

However, Lewis and Perry (2014) recently found that the planning process *kyozaikenkyu* can indeed engage newcomers in a somewhat profound manner when supported by the types of resources available to Japanese teachers, in this case a mathematical resource kit. Furthermore, Amador and Weiland (2015) found that PSTs, when observing a research lesson, managed to make higher-level comments than more knowledgeable others when given appropriate structure and guidance. They noted, however, that much of the content discussed during the lesson analysis meetings revolved around general classroom issues, such as the environment, management, or pedagogy, and that the highest level codes were absent; these were findings similar to those of the present study. Finally, Bocala (2015) advocates that newcomers should have access to knowledgeable experts who can support the social process of profound engagement with LS. This can be achieved by providing feedback and engaging the practitioners in deliberate reflection about and application of their new learning. The above scaffolding methods are all used by Japanese teachers to integrate the essential elements of LS into PST education (Elipane, 2012). These research findings thus support the present researcher's view that PSTs need scaffolding tools to engage profoundly with LS.

5.3 Limitations

The way the research was conducted in the present study, as described in Chapter 3, has influenced and limited the results, as described in several ways. Therefore, a discussion of these is necessary.

The first limitation arises from the fact that the data for the present project was collected through a time-lagged design, as discussed in sub-section 3.1.1. This means that the participants who contributed with data for the research during the CSP were different from those in the INT. Since participants vary in knowledge and ability, these individual differences may have influenced the results. However, after conducting a pairwise comparison of the CSP groups and the INT groups, Articles 1 and 2 reported that their profiles were similar. This indicates that the discovered differences were more likely to be a consequence of changes introduced by the INT than to personal differences, e.g. level of competency.

The second limitation is that the specific effects of the CoRe cannot be distinguished from the effects of the LS, as the research design has not included conditions where only LS or the CoRe have been used during field practice. This means that the specific contribution of the CoRe in the present study can only be inferred by, for example, referring to other research findings reported in the TasS project (e.g. Bjuland et al., 2015; Helgevold et al., 2013) or by comparing outcomes with what the CoRe and LS theoretically make the PSTs focus on, as argued through section 2.4.

The third limitation arises from the chosen PCK model for science (Magnusson et al., 1999), which has been found to represent knowledge (e.g., curriculum, assessment) as separate silos. The reason for this, as argued in sub-section 2.3.3, is due to considerations about the usefulness of the model, which most scholars accept as a fair trade-off (e.g. Kellner et al., 2010; Park & Oliver, 2008). However, other scholars argue that these artificial silos constrain our understanding of teachers' PCK conceptualization, since teachers do not organize their knowledge in a compartmentalized way (Friedrichen, 2015). The effects would be most prominent from the results of Articles 1 and 2. However, since Articles 3 and 4 use a more holistic methodology, the possible constraining effects would not be found to the same degree in this extended abstract.

The fourth limitation arises from the choice to omit the 'Orientation' component from the coding process when using the Magnusson et al.'s (1999) model in Articles 1 and 2, rather than including it as a part of the PCK elements. This choice was made primarily because of the focus of the present research project and also because of page limitations. These are both reasons used and reported by other researchers (Friedrichsen et al., 2011). Consequently, this research cannot say anything specific about how the PSTs' orientations influenced their choices, reasoning and arguments throughout the INT.

The fifth limitation concerns the choice of data focus for this research, which was limited to the first LS cycle. This is an obvious limitation, since one of the strengths of the LS method is that PSTs are able to revise the research lesson they have already taught, teach it again, and are then able to reflect on the experiences as a whole (C. Fernandez & Yoshida, 2004). This research thus portrays only a part of the LS process, and misses out on the opportunity to investigate the PSTs' development during two consecutive LS cycles. The reason for only studying the first LS cycle was due to considerations made about the overarching research design (section 3.1.), in which a comparison between the CSP and INT was considered necessary. This excluded the second LS round since the two situations at this stage were no longer comparable.

The sixth and final limitation is related to the consensus model (Gess-Newsome, 2015, Figure 5, p.37), which is a model developed after the data collection and analysis presented in Articles 1–4 were carried out. Therefore, the implications of the consensus model could not be included in the articles. With regard to Articles 1 and 2, the use of this model would probably not have changed much since the TSPK components (Figure 5, p. 37) present the same categories as the ones used by Magnusson et al. (1999, Figure 4, p. 33), and additionally place 'Orientations' as filters that the PCK elements 'go through' when developing PCK. Furthermore, the possible limitations have to some degree been avoided in this extended abstract, since the research findings in this extended abstract, as argued in sub-section 2.3.5, have been used to discuss the implications of these findings.

5.4 Conclusions

From the theoretical point of view presented in Chapters 1 and 2, it was argued that to better combine theory and practice, while also educating efficient teachers, teacher education should focus on the development of teachers' Pedagogical Content Knowledge. Furthermore, it was argued that the combination of Lesson Study and the form called Content Representation might be one way of achieving this goal. Therefore, this investigation has looked into the main research question: "*How does the use of Lesson Study combined with Content Representation affect pre-service science teachers' potential to start developing Pedagogical Content Knowledge during field practice in teacher education"*.

In this regard, Articles 1 and 2 specifically showed that the combination of Lesson Study and Content Representation promoted the pre-service teachers' potential to start developing Pedagogical Content Knowledge in four ways during planning and reflection when compared to typical practice. First, it provided the pre-service teachers with a more even focus on all the Pedagogical Content Knowledge categories. Second, it made the pre-service teachers focus less on general management and basic survival concerns. Thirdly, it led to the pre-service teachers focussing more on the pupils and their learning. Finally, it enabled the pre-service teachers to focus more on theoretical elements presented during teacher education.

Articles 3 and 4 further elaborated on these findings. Here it was found that the intervention made the pre-service teachers engage in a somewhat meaningful and connected manner with two important aspects of Pedagogical Content Knowledge, namely the teaching of a subject-matter aim and its assessment. According to previous research, both of these aspects have typically received little attention. Furthermore, the pre-service teachers were able to pinpoint and reflect on identified shortcomings. With regard to all of the above, the Content Representation form was found to function as a scaffolding tool during these difficult processes. However, the results from Articles 3 and 4 also questioned the depth of the pre-service teachers' expressed knowledge during the intervention. This indicates that the Lesson Study and Content Representation approach during field practice, even though it changed the pre-service teachers' focus in a positive way when judged from the perspective of Pedagogical Content Knowledge, only allowed these teachers to access its surface features.

5.5 *Implications for further research*

From the above discussion, it seems reasonable to conclude that PCK is an important and useful construct that can be critically used to assess PSTs' knowledge development in the process of becoming expert teachers. Therefore, PCK should be used to address the main challenge found by this study, namely how to make PSTs engage profoundly with the combination of LS and the CoRe.

Based on the present research, this study proposes to further engage with this problem in the following ways. First, more engagement with the planning process could be achieved by working through several pre-mentoring sessions before teaching the first research lesson. This typically happens when conducting LS (C. Fernandez & Yoshida, 2004). However, this did not happen in the current study due to time restrictions within the field practice period. Second, the complexity of conducting LS as newcomers could be reduced by facilitating the LS process through an experienced LS teacher (Bocala, 2015). The use of an experienced teacher has been found to be a highly contributing factor to keeping both a research lens and for engaging with the LS process in a more profound way (C. Fernandez et al., 2003). Likewise, Loughran et al. (2001) suggest that mentor teachers also need to understand the knowledge framework provided by PCK in order to have the greatest impact on teacher learning. Thirdly, another way of reducing the complexity could be to develop specific material for science on which the PSTs could model themselves. This is a powerful way employed by teacher education in Japan to engage newcomers in the LS method (Elipane, 2012), and which has shown promise within mathematics (Lewis & Perry, 2014). This could either be done by using LS to develop topic-specific textbooks and teacher manuals for science, or by adapting and using already developed LS material/CoRe, together with their PaP-eRs (Pedagogical and Professional experience repertoires) (Loughran et al., 2012).

In contrast to the present study, the above suggested research could follow several LS cycles. Furthermore, it could be conducted as a mixture of large scale and thorough studies, both to verify the present research and to uncover in-depth knowledge about quality.

This study has illuminated how the possibility PSTs have to start developing PCK may have changed through the introduction and use of LS in combination with the CoRe during teacher education field practice. This creates a robust foundation for future research, both within the same and other contexts, as described above. Teacher education may specifically benefit from introducing the CoRe in combination with LS as a means to create effective professional development programs. Nevertheless, it is important to recognize that if other research questions had been posed, if other theoretical views had been used, or if different methodological approaches had been applied, the research findings from the same material may have been different. Such different approaches are also suitable ways of expanding on the present research.

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Appendix

Appendix A - Different PCK conceptualizations for science shown by year

The content of the table is based on Park & Oliver (2008) and Kind (2009). Shulmans original PCK components have been marked with grey. Denotation with PCK means that the Scholar(s) placed this sub-category as a component of PCK. Denotation with K means that the Scholar(s) placed this sub-category outside of PCK, but as a distinct knowledge base for teaching. Denotation with 0 means that the scholar(s) did not discuss this sub-category explicitly.

Subject matter knowledge	Context for learning	General pedagogy/ classroom management	Assessment
K	K	K	0
K	0	K	PCK
K	0	0	0
K	K	K	PCK
PCK	0	0	0
PCK	PCK	PCK	0
0	0	0	0
PCK	PCK	0	0
PCK	PCK	PCK	0
PCK	PCK	PCK	PCK
K	K	K	PCK

Scholars	Representation and instructional strategies	Student's specific learning difficulties	Purposes/ orientations/ nature of science	Curricular knowledge
Shulman (1986)	PCK	PCK	K	K
Tamir (1988)	PCK	PCK	0	PCK
Smith and Neale (1989)	PCK	PCK	PCK	0
Grossman (1990)	PCK	PCK	PCK	PCK
Marks (1990)	PCK	PCK	0	PCK
Cochran et al. (1993)	0	PCK	0	0
Geddis et al. (1993)	PCK	PCK	0	PCK
Fernández-Balboa and Stiehl (1995)	PCK	PCK	PCK	0
Koballa et al. (1999)	0	PCK	0	PCK
Veal and MaKinster (1999)	PCK	PCK	PCK	PCK
Magnusson et al. (1999)	PCK	PCK	PCK	PCK

Appendix B – Coding scheme Article 1

Main coding categories	Sub Coding Categories
A - Display of Knowledge of Curriculum in Physics	A1. Goals for instruction - What do they intend the pupils to learn about this idea?
	A2. National, state, and or local standards.
	A3. Resources and content of textbooks (i.e. specific knowledge of things included in curricular materials).
	A4. Scope and sequencing of Physics topics - How are things connected in the curriculum? Where did it come from? Where is it going?
B - Display of Knowledge of Pupils' Understandings within Physics	B1. Prior knowledge - What have they learned in prior lessons or years?
	B2. Motivators, difficulties - When do they find certain concepts motivating or demotivating, easy or hard to understand?
	B3. Misconceptions (i.e. random mistakes, alternative conceptions, intuitive ideas, misconceptions).
	B4. Strategies pupils use to approach, solve and understand a concept or problem.
C - Display of Knowledge of Instructional Strategies for Physics	C1. Pupil's behaviour that could influence teacher's way of instructing.
	C2. Discussion of best representations and actions to use for specific content (i.e. specific models or ways of presenting an idea).
	C3. Elaborating on specific activities, measures and materials to use for physics content.
	C4. How to organize and sequence instruction and observations for specific content.
D - Display of Knowledge of Assessment for Physics	D1. Purposes and reasons for assessment - what do we want to find out and what are the reasons behind this?
	D2. Varied, best strategies and challenges for assessment - Discussion of different strategies and challenges entailed in choosing one.
	D3. Specific method, material and placement of assessment for content - elicitation process, including challenges, materials and when to do it.
	D4. Hypothesis about pupil thought patterns, responses and potential teacher responses - how they as teachers will use and respond to the collected assessment knowledge.
Other	Data that clearly does not fit into any of the four main categories.

Appendix C – Coding scheme Article 2

Main coding categories	Sub Coding Categories
A - Reflections on displayed knowledge for curriculum in Physics	A1. Reflections on goals for instruction
	A2. Reflections on national, state, and or local standards
	A3. Reflections on resources and content of textbooks (i.e., specific knowledge of things included in curricular materials)
	A4. Reflections on scope and sequencing of physics topics
B - Reflections on displayed knowledge of pupils' understandings within Physics	B1. Reflections on prior knowledge
	B2. Reflections on motivators, difficulties
	B3. Reflections on misconceptions (i.e. random mistakes, alternative conceptions, intuitive ideas, misconceptions)
	B4. Reflections on strategies pupils use to approach, solve and understand a concept or problem
C - Reflections on displayed knowledge of instructional strategies for Physics	C1. Reflections on student behavior and ability that could influence teachers' way of instructing
	C2. Reflections on best representations and actions to use for specific content (i.e. specific models or ways of presenting an idea)
	C3. Reflections on specific activities, measures and materials to use for physics content
	C4. Reflections on organization and sequencing of instruction for specific content
D - Reflections on displayed knowledge of assessment for Physics	D1. Reflections on the purposes and reasons for assessment
	D2. Reflections on different and best strategies for assessment
	D3. Reflections on the specifically used assessment method and results from it
	D4. Reflections on hypotheses about pupils' thought patterns, enacted thought patterns and teacher responses
Other	Data that clearly does not fit into any of the four main categories.

Appendix

Appendix D – Coding examples of Article 1 & 2

To give the reader a better insight into the coding done as a part of article 1 & 2, then this sections provide specific coding examples. The aim has been to provide the most clear examples. Yet, in many cases the final choice of category can not be determined from the coded sentences alone, since they also are determined by the context in which the sentences are made. Full descriptions of the codes are provided in Appendix B (Article 1) and Appendix C (Article 2).

Article 1 planning

Code	**Example**
A1:	I have written down some goals. And we have now planned two lessons that they all will be taught. … let's see, I guess that we wrote down energy, there were however none of them [pupils] who started with that.
A2:	Because that which is stated in the national standards is that the pupil's needs to make simple calculations that includes [the scientific terms] work, energy and effect. If you read in the national standards and look into what it says about sound – you got a copy of that. There it says that you have to conduct experiments with sound, hearing and noise. That they need to be able to explain the results of the experiments and how you protect yourself against unwanted noise.
A3:	Yes. I actually never noticed that before, that is very unclear. It says that a person's mass is 60 kg, therefore they use that notation. However, they have not used it there. But, what content would you have stressed in exactly this chapter, what would you have chosen to focus on?
A4	Very good. For sound is a subject in the 6. grade books while light first comes in the 7. grade book. And light is somewhat connected with electricity. …. So then they work with energy and effect… before the others.
B1:	So they have been taught about energy, different forms of energy and the energy law. We wondered about which formulas they have used in prior lessons…

B2:	We do not need to start which such a huge calculation on the blackboard, because then many will not be able to follow. … But I was thinking that the cleaver pupil's they will manage, but the pupils who think that it is somewhat difficult to start with could think that it is too much.
B3:	I was thinking that we have a lot of energy in our bodies in a way. You often say: Oh I have so much energy. Like you got to get the energy out. I am thinking when you have to introduce that subject. What do you need to have in focus when you are introducing it, concerning that the pupil's in fact have different misconceptions and alternative conceptions.
B4:	Many of them know. Many of them like to build things and know that when you need to shoot an object, then you draw down the throwing arm and that the more you draw the further it goes. But I do not think that they connect this with an increase in potential energy when they shoot. I have not thought a lot about that in any case. I just thought, simply move it further back then it throws harder.
C1:	Are there any pupils who are not allowed to work together? Those two we have talked about, but… It could be the case that some pupils won't participate and that they neither want to write or to draw the energy chain.
C2:	It might be good to write the names instead of using those letters, since that it might create confusion. Because, then they use W for work but they also use W for watt. In that way there would be less to write down, however to write is also a good strategy since it calms the pupil's down. It is easy, since then they have something to do.
C3:	But he also uses movement and kinetic energy, so it is something that he… I believe that he explained that movement often is like this… However, we have to say it either before or after the movie and…. He uses somewhat different scientific terms than the ones written in the book. But maybe we can mention it one time more when showing that example and then proceed to… What is it… What is it that happens with those dominos…
C4:	Well, we have to repeat the types of energy in the start… I believe that we wrote that down… that we had in the end of the last science lesson. Well it would also be ok just to keep on working and then if we do not get time for the catapult, then we just don't.
D1:	I was thinking when if you think about the work assessment, what does

	that mean. Do you assess when you watch? Do you have to assess yourself and your own teaching of is it the pupil's and their learning that you need to assess?
D2:	And then I wish to jump straight to assessment… What have you thought about that, for now you do have the learning aims… How would you go around to assess the pupil's when having those learning aims? We thought, if we use it in that lesson, then we would not get any out of in straightaway. Afterwards however we could use it as a part of the assessment and furthermore plan out to look into how.
D3:	We have used this test on them to figure out what they know from before. Therefore, we thought about that it could be cool to use that test again afterwards. And then we would test this, since it covers energy sources and… We thought to have a quiz.
D4:	So it might be that they are paying attention even if they do not show things that you clearly can observe… so even though they might understand. And if it gets warm, which type of energy do you believe that it is. It has to be heat energy. I believe that the pupil's will manage that, since they can feel it in their own bodies. And then hear sound, which is movement, then it is easy to understand that it is kinetic energy.

Article 2 reflection

Code	**Example**
A1:	No, you managed to connect the things again, when you wrote the learning aims on the blackboard. The content is sound. And that is a choice that you do, for afterwards the aim was very clear.
A2:	What we were wondering about, but that we forgot, was how much of this is relevant for the pupil's during the whole day exams and such. And then it is also, in the national standards, it is in focus that the pupils should be able to do…
A3:	In the teacher's guide it said nothing specific about that assignment. It only gave a general description but did not present how the calculation was done. Yes. But try instead to look at the guide to the Tellus books, maybe they say something about it. Also they might write about activities that you can

	use.
A4	No coded examples.
B1:	The different energy types. Those I think that they can, but they do no put them into words, they cannot put them into words. But they do know about them. They are not strange to them. Those are the most important of the scientific terms they know in a way.
B2:	They express somewhat weaker understanding, if I can say that, than some of the others that performed better. They have a medium level, and therefore they might be influenced by that. I was somewhat more negative to the catapult before I saw the interest that it created… and when they are interested then they are also motivated I think.
B3:	How you get a hold of the pupil's misconceptions. To focus on how to make their misconceptions into right understandings. The reason is that there is a lot of pupil's who has different thoughts than theirs, and that they therefore are unsure if their way of thinking is the correct one, since they have seen an energy chain that is like that.
B4:	And then I saw several pupils made nodes when we came to that one. That is very good. No. And he had read it in his own. He nearly felt like he had cheated.
C1:	That D class was insignificant when compared with the E class, when it comes to be silent. Then it was nothing. Well it is the first lesson when they usually are… It is the first lesson of the day.
C2:	But I see now that we should have used even more, even more practical examples. Yes, in that way they work with both and then you also work with their understanding.
C3:	The only thing that I also noticed was that the pupils found out and struggled with the fact that you drew the arrows the wrong way. With that turbine you know. I would have liked to link those things that I taught first as repetition with those other ones. To link them more with what was taught later.
C4:	I did not know at all that I used that long time on that subject, you forget. You do not think about the time when you are standing there.

	But like today when they are working with an experiment, then I believe that it is totally ok to interrupt them with common messages that might help them in their further work.
D1:	No coded examples.
D2:	You would get an opportunity to see how they would solve it. An opportunity to let them try, and then show them the correct answer. And then see if then it is easier for them to understand.
D3:	He said that what he liked the least about the lesson was the repetition during the start, since they already had that in the last lesson. Therefore, I am not sure that we need to use so much time on that. One of the reasons is that S who I also see as an able learner, she was a little doubtful. And then I think, if she is doubtful, then there is many who are doubtful.
D4:	No coded examples.

Appendix

Appendix E – NSD approval

Norsk samfunnsvitenskapelig datatjeneste AS
NORWEGIAN SOCIAL SCIENCE DATA SERVICES

NSD

Raymond Bjuland
Institutt for allmennlærerutdanning og spesialpedagogikk
Universitetet i Stavanger
4036 STAVANGER

Vår dato: 10.01.2012 Vår ref: 28919 / 3 / AH Deres dato Deres ref

KVITTERING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 05.12.2011. All nødvendig informasjon om prosjektet forelå i sin helhet 12.01.2012. Meldingen gjelder prosjektet:

28919	*Studenter lærer av elever*
Behandlingsansvarlig	*Universitetet i Stavanger, ved institusjonens øverste leder*
Daglig ansvarlig	*Raymond Bjuland*

Personvernombudet har vurdert prosjektet og finner at behandlingen av personopplysninger er meldepliktig i henhold til personopplysningsloven § 31. Behandlingen tilfredsstiller kravene i personopplysningsloven.

Personvernombudets vurdering forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, eventuelle kommentarer samt personopplysningsloven/helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/forsk_stud/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://www.nsd.uib.no/personvern/prosjektoversikt.jsp.

Personvernombudet vil ved prosjektets avslutning, 21.12.2015, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Vigdis Namtvedt Kvalheim Åsne Halskau

Kontaktperson: Åsne Halskau tlf: 55 58 89 26
Vedlegg: Prosjektvurdering

Personvernombudet for forskning

Prosjektvurdering - Kommentar

Prosjektnr: 28919

Prosjektets formål er å se på hvilke ytelser som er til stede i lærerutdanningen i dag som støtter studentenes læring av det å undervise, og om man kan forbedre studentenes læring ved å implementere "lesson study" -tilnærminger til det å lære undervisning. Utvalget består av grunnskolelærerstudenter ved en institusjon, praksislærere og fraglærere, samt elever.

Førstegangskontakt med studentene opprettes via deres faglærere ved UiS. Frivilligheten understrekes ved førstegangskontakten. Førstegangskontakt med lærere og elever opprettes via skolene. Ombudet legger til grunn at ledelsen ved skolene og UiS har godkjent prosjektet som helhet.

I 2012 (vår) skal det gjennomføres fokusgruppeintervju med studenter før og etter praksisperioden. Det vil registreres opplysninger om informantenes fagkunnskap før praksisopplæring og etter, samt se på opplysninger om hvorvidt studentene ser på mangfold i skolen som en ressurs eller en hindring. Deretter skal planlegging, gjennomføring og etterveiledning av undervisning filmes i to sekvenser i hver praksisgruppe. Elever, studenter, faglærere og praksislærere vil være inkludert i filmmaterialet. Hensikten er å fange opp hva studentene mestrer i praksisopplæringens "normalsituasjon; før intervensjonen. I løpet av 2013 vil det deretter gjennomføres en intervensjon, dvs. at det gjennomføres en identisk datainnsamling, men hvor det er integrert "lesson studies" og mer veiledning fra faglærere ved UiS direkte inn i praksisopplæringen.

Prosjektleder opplyser på telefon 18.01.2012 at det kan bli aktuelt å gjennomføre en spørreskjemaundersøkelse rettet mot studentene i etterkant av intervensjonen. Spørreskjemaundersøkelsen er imidlertid ikke utarbeidet ennå. Ombudet ber derfor om at denne delen av prosjektet sendes som en endringsmelding i god tid, og senest 30 dager før denne delen av datainnsamlingen skal settes i gang. Endringsmeldingsskjema finnes her http://www.nsd.uib.no/personvern/forsk_stud/skjema.html

Ombudet legger til grunn at veileder og student setter seg inn i og etterfølger Universitetet i Stavanger sine interne rutiner for datasikkerhet, spesielt med tanke på bruk av bærbare enheter til oppbevaring av personidentifiserende data. Vi anbefaler at alle filer som inneholder personopplysninger om deltakerne krypteres.

Det skal gis informasjon skriftlig og innhentes samtykke skriftlig. Ombudet har mottatt informasjons- og samtykkeskriv for studenter, praksislærere og øvingslærere 15.01.2012 og for elevenes foresatte 19.01.2012 og finner dem tilfredstillende utformet. Personvernombudet finner at behandlingen kan hjemles i personopplysningsloven § 8 (samtykke).

Prosjektslutt er angitt til 21.12.2015. Senest ved prosjektslutt vil video- og lydopptakene være slettet, og det øvrige datamaterialet anonymisert. Ombudet minner om at et anonymt datamateriale kun består av opplysninger som ikke på noe vis kan identifisere enkeltpersoner, verken direkte gjennom navn eller personnummer, indirekte gjennom bakgrunnsvariabler, eller gjennom navneliste/koblingsnøkkel eller krypteringsformel.

Appendix F – Article 1

Juhler, M. V. (2016). The use of lesson study combined with content representation in the planning of physics lessons during field practice to develop pedagogical content knowledge. *Journal of Science Teacher Education*, *27*(5), 533–553.

Appendix

Appendix

The use of Lesson Study combined with Content Representation in the planning of Physics lessons during field practice to develop Pedagogical Content Knowledge

Abstract

Recent research, both internationally and in Norway, has clearly expressed concerns about missing connections between subject-matter knowledge, pedagogical competence and real life practice in schools. This study addresses this problem within the domain of field practice in teacher education, studying pre-service teachers' planning of a Physics lesson. Two means of intervention were introduced. The first was Lesson Study (LS), which is a method for planning, carrying out and reflecting on a research lesson in detail with a learner and content-centred focus. This was used in combination with a second means, Content Representations (CoRe), which is a systematic tool that connects overall teaching aims with pedagogical prompts. Changes in teaching were assessed through the construct of Pedagogical Content Knowledge (PCK). A deductive coding analysis was carried out for this purpose. Transcripts of pre-service teachers' planning of a Physics lesson were coded into four main PCK categories, which were thereafter divided into 16 PCK sub-categories. The results showed that the intervention affected the pre-service teachers' potential to start developing PCK. Firstly, they focused much more on categories concerning the learners. Secondly, they focused far more uniformly in all of the four main categories comprising PCK. Consequently, these differences could affect their potential to start developing PCK.

Keywords: Pedagogical Content Knowledge (PCK), Lesson Study (LS), Content Representation (CoRe), Field practice, Development, Science teacher

Educating pre-service teachers - a call for connections between subject-matter knowledge, pedagogical competence and real life practice

International and national evaluations have found that the components of teacher education, namely the teaching of subject-matter, pedagogy and field practice, are often taught separately (Hammerness & Klette, 2015; Hart, Alston, & Murata, 2011; NOKUT, 2006; Norgesnettrådet, 2002; Zeichner, 2010). These findings stand in contrast to the belief that skillful teachers need a deep understanding and integration of all of the aforementioned components (Gess-Newsome, 2015; Shulman, 1986). Therefore, the challenge of combining theory and practice is a concern for teacher education in general. However, it is a specific concern within field practice, since one of the main aims in this context is *to connect theory with practice* (Allsopp, DeMarie, Alvarez-McHatton, & Doone, 2006; Canrinus, Bergem, Klette, & Hammerness, 2015).

In this respect, researchers have been interested in finding out why pre-service teachers generally do not apply the theory they have learnt during teacher education when planning a practice lesson during field practice (Bradbury & Koballa, 2007; Gess-Newsome & Lederman, 1999). What they found was that mentoring teachers generally seemed to minimize the importance of the subject-matter content during mentoring sessions (Bradbury & Koballa, 2007; Skagen, 2000) and avoided asking critical questions (Skagen, 2000). Instead, they tended to focus on general pedagogical knowledge, as well as general classroom management (Bradbury & Koballa, 2007). In such circumstances, good field practice training seems to boil down to handling issues about proper sequencing (Handal & Lauvås, 1987), with the implementation of 'tasks that work' (Grossman, 1990). They also found that a consequence of pre-service teachers' lack of content knowledge when planning a lesson (Harlen, 1997) was that they followed the order and recipes of textbooks (Appleton, 2003; Gess-Newsome & Lederman, 1999; Talbert, McLoughlin, & Rowan, 1993), or that they relied on memories collected through their own experiences as learners. When planning in this way, the main content of the prepared lessons becomes dependent on 'activities that work' (Appleton, 2003, 2006). It also leads to concerns about enactment, with survival concerns in mind (Kagan, 1992), and with a subsequent focus on general classroom management (Bradbury & Koballa, 2007; Gess-Newsome & Lederman, 1999; Kagan, 1992; Weiland, Akerson, Rogers, & Pongsanon, 2010). These are all reasons for why pre-service teachers often fail to understand the complexity and sophistication of the thoughts and knowledge needed to plan and conduct a lesson (Kinchin & Alias, 2005; Munby, Russell, & Martin, 2001), thereby preventing them from becoming skillful teachers. A skillful teacher is hereby understood as one who recognizes and understands the complexity of teaching, and who sees the value of transforming knowledge into a form that is useable and helpful in shaping teaching (Nilsson, 2008).

Within the domain of science teaching, more and more researchers believe that one way of combining theory and practice is to focus on pre-service teachers' development of Pedagogical Content Knowledge (PCK) (e.g. Anderson & Mitchener, 1994; Van Driel & Berry, 2012). The reasoning for this is that developing PCK entails a deep knowledge of the connection between and integration of subject-matter knowledge, pedagogical competence and real life practice (Shulman, 1986, 2015). As such, many current researchers think of PCK as the developmental objective of the skillful teacher (Abell, 2007; Appleton, 2008; Henze, Van Driel, & Verloop, 2008; Lee & Luft, 2008; Loughran, Berry, & Mulhall, 2012; Nilsson, 2008; Park & Oliver, 2008). The challenge thus becomes how teacher educators can help pre-service teachers to develop PCK during science field practice.

In this respect, recent research has shown that the use of the method Lesson Study (C. Fernandez & Yoshida, 2004; Lewis & Tsuchida, 1999) and the tool Content Representation (CoRe) (Loughran et al., 2012) individually have the possibility to develop pre-service science teachers' PCK (Nilsson & Loughran, 2011; Padilla, Ponce de León, Rembado, & Garritz, 2008; Pongsanon, Akerson, & Rogers, 2011; Weiland et al., 2010). It can therefore be argued that CoRe should be used together with Lesson Study, since CoRe is a possible aid to those unfamiliar with the Lesson Study method. Hart et al. (2011) discovered that those who were unfamiliar with Lesson Study struggled to engage sufficiently with the planning process. It therefore stands to reason that pre-service teachers need a scaffolding tool which will help them to sufficiently engage with the planning process, something that the CoRe tool seems able to provide (Loughran et al., 2012). However, within the context of field practice in science teacher education, there is a paucity of research that focuses on the effect of Lesson Study on the development of PCK (i.e. Pongsanon et al., 2011; Weiland et al., 2010). The same applies to the CoRe tool (i.e. Hume & Berry, 2013; Nilsson & Loughran, 2011). More importantly, none of the above-mentioned researchers have tried to use Lesson Study in combination with CoRe.

The stage is thus set for an intervention study, introducing both the Lesson Study method and the CoRe tool in science pre-service teachers' field practice. In this way, the current research will add to prior research on mentoring, PCK, Lesson Study and CoRe. Specifically, it will add new knowledge about the combination of Lesson Study and CoRe. This is accomplished through addressing the following research question:

> *How does the use of Lesson Study combined with Content Representation affect pre-service science teachers' potential to start developing Pedagogical Content Knowledge while planning a research lesson during field practice?*

The research presented in this article is part of the Norwegian TasS (Teachers as Students) project (2012-2015). The aim of TasS was to investigate pre-service teachers' learning during field practice, focusing on the subjects English, Physical Education, Mathematics and Science. The current research specifically addresses the subject of Physics as a subset of science, since this was the subject taught during the field practice period in question. The current study was conducted during a period of two years (2012-2013), with each year involving research on two pre-lesson mentoring sessions with two groups of pre-service teachers. In the first year (2012), field practice was carried out according to the university guidelines (Ministry of Education, 2010), namely representing the 'normal' situation. In contrast, field practice in the second year (2013) was conducted as an intervention using LS in combination with CoRe.

The article initially explains the theoretical foundation for using PCK as a developmental goal for teacher education and as a framework for the assessment of the intervention study. Secondly, it addresses why LS and CoRe can supposedly be used to develop the pre-service teachers' PCK. Subsequently, the applied research design is described, after which the results are presented and discussed in the light of the theory presented. Finally, conclusions are drawn about the effect of the intervention on the pre-service teachers' potential to start developing PCK.

PCK for science

Shulman first introduced the term 'Pedagogical Content Knowledge' (PCK) in 1986 (Shulman, 1986). The term was introduced as a way of trying to understand the complex relationship between teaching and content through the use of specific teaching approaches developed through classroom practice. As such, Shulman defined PCK as having the following:

> *An understanding of the most useful forms of representation – most powerful analogies, illustrations, examples, explanations and demonstrations. 2. An understanding of what makes learning of specific topics easy or difficult: the conceptions and preconceptions that pupils of different ages and backgrounds bring with them. 3. Knowledge of strategies most likely to be fruitful in reorganizing the understanding (Shulman, 1986, pp. 9–10).*

This definition of PCK refers to the teacher's integration of subject matter, content and pedagogy in ways intended to enhance pupils' learning during teaching (Nilsson, 2008). Therefore, PCK becomes a good framework for linking the traditionally separated knowledge bases of content and pedagogy to practice (Anderson & Mitchener, 1994; Van Driel & Berry, 2012).

Following Shulman's definition of PCK in 1986, many researchers developed his ideas further (Berry, Friedrichsen, & Loughran, 2015). One of these developments within the area of science is Magnusson et al.'s model, 'Components of PCK for science teaching', depicted in Figure 1 (Magnusson, Krajcik, & Borko, 1999, p. 99). This is a model used by a number of researchers (e.g. Abell, 2007; Appleton, 2008; Henze et al., 2008; Lee & Luft, 2008; Park & Oliver, 2008). Recently, a new consensus model of PCK called 'Teacher Professional Knowledge and Skill' (TPK&S) has been published (Berry et al., 2015). The present research pre-dates its development. Yet, by comparison it can be seen that the TPK&S model contains the same main content presented in Magnusson et al.'s model. One main difference highlighted though is that 'Orientations' in the TPK&S model, is seen as a filter that the four knowledge components 'go through' when developing PCK (Gess-Newsome, 2015).

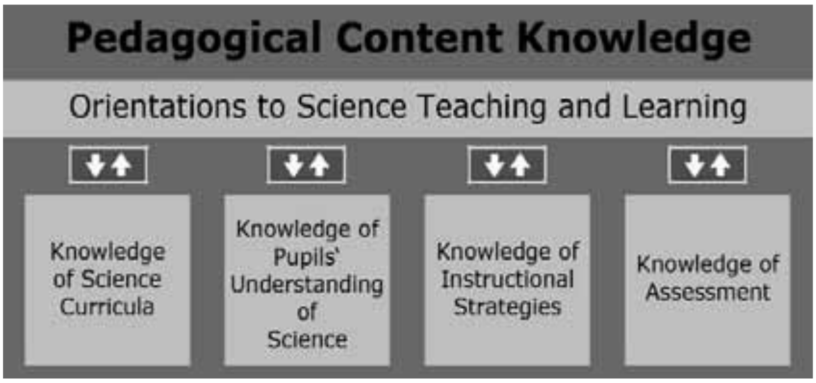


Figure 1: Components of PCK for science teaching' (Magnusson, Krajcik, & Borko, 1999, p 99)

Magnusson et al.'s model is comprised of one overarching component: 'The teacher's orientations to science teaching and learning'. This component refers to the teacher's knowledge and beliefs about both the purposes and goals for teaching science at a particular grade level, something that both influences and is influenced by the four components depicted in the bottom of the figure. The first of these components is 'The teacher's knowledge of science curricula'. This component refers to knowledge about mandated goals and objectives, as well as specific curricular programs and materials. This knowledge, in turn, relates to specific topics, across topics and development over different school years. The second component, 'Knowledge of pupils' understanding of science', refers to knowledge about requirements pupils need in order to learn specific concepts, i.e. an understanding of pupils' approaches to learning a subject and the abilities and skills they need. This category also refers to areas of science that pupils find difficult, and the reasons why they find them difficult. The third component, 'Knowledge of instructional strategies', refers to knowledge of subject-specific strategies and knowledge about general approaches to or overall schemes for enacting science instruction. This component also refers to the knowledge of topic-specific strategies that are useful to help pupils comprehend specific science concepts. The fourth category, 'Knowledge of assessment', refers to knowledge of dimensions of science learning within specific topics that are important to assess. This category also includes knowledge of specific assessment methods and how they can be used to assess specific aspects of pupils' learning within a particular unit of study (Magnusson et al., 1999). These four components depicted in the bottom of the model create the framework for this study, a goal of development so to speak, and the components are used to show and assess what PCK pre-service teachers focus on while planning a field practice lesson.

How Lesson Study and Content Representation can support PCK development

Since the development of PCK does not happen by itself, it is necessary for teacher education to have methods and tools to help both the mentoring teachers and pre-service teachers to define, identify and access the construct of PCK. In the following, it will be argued why using the Japanese instruction method Lesson Study, in combination with the scaffolding tool Content Representation, might be one way of developing pre-service teachers' PCK during field practice. Lesson Study (LS) is a method of deliberate praxis. This method has been proven during recent studies in both Japan and the US to lead to positive effects on the development of teachers' PCK (Lewis & Tsuchida, 1999; Weiland et al., 2010), which is why it has been chosen as the main intervention method in this study.

A main component of the LS method is moving through the LS cycle, as shown in Figure 2 (C. Fernandez & Yoshida, 2004). During this cycle, a team of educated teachers would normally work together. However, in this study the groups consisted of one experienced mentoring teacher working together with either three or four pre-service teachers. All the members of the group bear equal responsibility when working through the following steps: 1) Production of overarching goals and specific academic goals for the lesson being studied. A research question is formulated, encapsulating what the pre-service teachers want to learn more about, and aiming at gaining knowledge about the pupils' learning process. 2) Group discussion and production of very detailed lesson plans for the lesson to be taught. The focus is on prediction of choices (e.g. implemented activities and measures) and their consequence for pupils' learning (what could be

Figure 2: Lesson Study Cycle (C. Fernández & Yoshida, 2004)

problematic). 3) Normally, one teacher is chosen by the group to teach the lesson. However, in this study it was done by drawing lots, thereby ensuring that all of the pre-service teachers would engage equally in the LS. Those who do not teach the lesson, observe it and collect data about the pupils, which sheds light on the initial research question they have posed. 4) The lesson plans are subsequently reflected upon and revised according to the observations made during the lesson. New predictions are then made, reflecting the consequences of the newly-implemented changes. 5) A new teacher is thereafter chosen by the group. In this study, this again happens by drawing lots. The chosen teacher subsequently teaches the revised lesson to another group of pupils. Once again the lesson is observed by those who do not teach it; they collect data about the pupils, which sheds light on the initial research question and observations made during the first taught lesson. 6) The results of the findings from the observations connected to the research question are then assessed and in turn disseminated so that knowledge might be shared.

Working through the LS steps, as described above, specifically helps to set an active agenda by utilizing research-based knowledge as a natural and essential part of the focus for the group doing the research, thus possibly developing their PCK. It does so by focusing the research group's attention on the content knowledge being taught (Figure 1. Sub-component 1). It guides the teachers' thinking towards the pupils' perspectives, planning around different possible problems, solutions, responses and ways in which the pupils can react (Figure 1. Sub-component 2). This is discussed in detail in relation to the learning outcomes of the pupils, and how they can find out what they have learnt (Figure 1. Sub-component 4), which is linked to a specific way of instructing the pupils (Figure 1. Sub-component 3) (C. Fernandez & Yoshida, 2004; Murata & Pothen, 2011). This might be the reason why recent research on LS shows that when working through the LS cycle, teachers develop a deeper and more substantial knowledge of the subject. Furthermore, their general attitudes towards teaching change as they now design lessons that are more content-centred, learner-centred, engaging, and supportive of learning, with a clear focus beyond concerns to do with basic survival and classroom management (C. Fernandez & Yoshida, 2004; M. Fernandez, 2005; Marble, 2007).

However, Hart et al. (2011) discovered that many teachers, often those unfamiliar with the LS method, fail to conduct LS in a way that truly impacts their PCK. The main reason for this is that they do not manage to engage with the planning stage in a profound way. Therefore, it stands to reason that newcomers need a tool that can help to scaffold this process, while also focusing on PCK development. The Content Representation (CoRe) tool seems to be able to achieve exactly this since it was developed both to capture experienced science teachers' PCK and to be a tool for the development of their PCK (Loughran et al., 2012; Loughran, Mulhall, & Berry, 2004). Furthermore, it scaffolds the process of planning by adding structure and coherence (Johnston & Ahtee, 2006; Loughran, Mulhall, & Berry, 2008), while also making it easier for the teachers to voice their tacitly held knowledge about teaching a specific topic (Nilsson & Loughran, 2011; Padilla et al., 2008; Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008). This is all done through a CoRe form, which has to be filled in (see Figure 3: CoRe-form) (Loughran et al., 2012).

Content: Age of children:	Big Idea A	Big Idea B
What you intend the pupils to learn about this idea.		
Why it is important for the students to know this.		
What else you know about this idea (that you do not intend students to know yet).		
Difficulties/limitations connected with teaching this idea.		
Knowledge about students' thinking which influences your teaching of this idea.		
Other factors that influence your teaching of this idea.		
Teaching procedures (and particular reasons for using these to engage with this idea).		
Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses).		

Figure 3: CoRe Form (Loughran, Berry, & Mulhall, 2006)

Essentially, the CoRe form challenges the teachers' thinking about teaching a science topic, based on the recognition of the 'big ideas' for that topic. These ideas are mapped against pedagogical prompts, including: 'what pupils should learn about each big idea', 'why it is important for pupils to know these ideas', 'pupils' possible difficulties with learning the ideas' and, 'how these ideas fit in with the knowledge the teacher holds about that content' (Nilsson & Loughran, 2011). Here 'big ideas' are understood as those that a teacher considers as being at the heart of understanding a specific science topic for a particular class under consideration (Mulhall, Berry, & Loughran, 2003; Smith & Girod, 2003). In this way, CoRe provides a holistic overview of how teachers approach the teaching of a topic and the reasons behind it. It also provides ways of linking the ‘why’ and ‘what’ of the content to be taught with the pupils who are to learn that content, in the form of propositions (Mulhall et al., 2003).

Research on CoRe shows that by working through the CoRe form in this structured way, pre-service teachers might understand that learning about science teaching (Figure 1. Sub-component 1) is closely linked to learning about pupils’ learning (Figure 1. Sub-component 2). In this way, pre-service teachers become more responsive to pupils’ learning, thereby enhancing their teaching knowledge and skills. This cognizant way of responding to pupils’ learning leads to the careful consideration of simply implementing activities that work (Figure 1. Sub-component 3); their concern is not only with how the activities might work, but also why (figure 1. Sub-component 4) (Loughran et al., 2008; Nilsson & Loughran, 2011). Reflection as a group around the filling-in of the CoRe form thus becomes a key component in helping pre-service teachers to reorganize their understanding (Schneider & Plasman, 2011), and to work towards an integration of theory and practice. This helps the pre-service teachers to actively develop their PCK for science (Nilsson & Loughran, 2011). Furthermore, it is important to note that the described aspects of the CoRe thought to develop PCK, also correlate with many of those promoted by the Lesson Study method. In this way they may possibly work together to create a synergy effect.

Research design and method

Data collection

The data for this study focuses on Physics and was collected as part of the aforementioned TasS project. The data was gathered over a two-year period, 2012 and 2013. This was done through a time-lagged design experiment (Hartas, 2010), which means that there were different participants in each of the two years.

<u>The two conditions, year 2012 and 2013</u>

During the first year (2012), those working with science in the TasS project followed two groups that prepared and conducted practice as described in the National Curriculum Regulations (Ministry of Education, 2010), adhering to the "normal" way field practice is conducted. These groups function as control groups and provide knowledge about the Current State of Practice (CSP). The National Curriculum Regulations (Ministry of Education, 2010) prescribe a total of 100 days of field practice at partner schools throughout the four years it takes to become a qualified teacher. Three of these weeks were carried out during the CSP. Mentoring is compulsory during this period; however, there is no mention in the Curriculum Regulations of its purpose, extent or execution. However, the reflective model developed by Handal and Lauvås (1987) is known to have had a great impact on Norwegian field practice (Sundli, 2007). The key to this model is reflection, which is thought to be best stimulated by asking questions as a way of providing scaffolding for the pre-service teachers in their efforts to build warranted accounts of classroom practice (Ottesen, 2007). The Curriculum Regulations further state that mentoring teachers should be qualified in mentoring, and that teacher education institutions should provide courses for these teachers.

During the second year (2013), an intervention (INT) was introduced. The INT consisted of the introduction and use of Lesson Study (LS) in combination with Content Representation (CoRe), and was used by both the pre-service and mentoring teachers. CoRe was added specifically to the science course in conjunction with this study, whereas the other subjects did not use it. LS and CoRe were introduced by researchers from TasS who were specialists in science. Firstly, the mentoring and pre-service teachers were presented with general theory on LS and CoRe. Secondly, they were shown examples of how these tools have been used. Finally, these examples were discussed in both groups and in plenary. Following the discussion, the mentoring teachers were presented with scaffolding material for the intervention. This comprised of theoretical articles explaining the concepts of both LS and CoRe. It also included an LS manual, developed specifically by the researchers in TasS for the Norwegian context. This manual has now been developed further and published (Munthe, Helgevold, & Bjuland, 2015). The manual emphasizes the importance of developing a good research question, guided by predictions and observations about and from practice. To ensure a deeper understanding of how to use the CoRe, the two researchers and the two mentoring teachers met shortly before the start of the practice period. As a group, they worked through and completed a CoRe form in detail for the given subject within Physics. From this stage on, the researchers only assisted in clarifying questions that were mainly connected to the material handed out.

Appendix

Participants in the study

The participants in the study consisted of fourteen pre-service teachers and four mentoring teachers. For each of the two years of the study, seven pre-service teachers and two mentoring teachers agreed to become the subjects of the research. In both the CSP and INT, the participants worked in two groups; one group consisted of three pre-service teachers in addition to a mentoring teacher, while the other consisted of four pre-service teachers and one mentoring teacher. In addition, two university science lecturers who were also part of the TasS research team joined the project for both years. During the CSP and INT, the original intention was for both the mentoring and pre-service teachers to be randomly selected from the geographical area covered by this specific teacher education program. However, the number of volunteers was very small, and the sample instead thus became one of convenience. The fourteen participating pre-service teachers were of both genders and in their early twenties. During the CSP, the participants were in their third year of teacher education, while those involved in the INT were in their second year. This came about because of changes at the administrative level at the university.

Teacher education in Norway is divided into two areas of specialization, one focusing on teaching grades 1-7 and the other on grades 5-10. In both the CSP and INT, one group focused on the teaching of grades 1-7 and one on grades 5-10. However, since few pre-service teachers choose to study science, they were all taught as one combined science class. Although they were all studying science at the time of the study, they had not yet begun their training in Physics. The grouping of pre-service teachers for field practice was carried out by the teacher education administration. The administration first divided the pre-service teachers into clusters, based on both subject and grade focus. They were then randomly divided into field practice groups consisting of either three or four pre-service teachers. Finally, the individual groups were allocated a mentoring teacher. This was based on the subject-focus of the pre-service teachers. The four participating mentoring teachers were qualified teachers who had different backgrounds in terms of qualifications in mentoring and years of experience as mentoring teachers.

Data collected for the study

Data was collected for TasS through two cycles of planning, teaching and reflecting during field practice, a decision based on the steps in the Lesson

Study cycle. The data for the current study was taken from the planning session during the first cycle since the CSP and INT were similar during this stage. In the second cycle, however, they differed since the INT group taught an improved version of the lesson from cycle one and the CSP group taught a whole new lesson. The planning sessions in both situations were self-recorded and carried out as conversations between the mentoring and pre-service teachers. During these conversations, only a few documents were present and used during the CSP. However, during the INT, source books, a filled-in CoRe form and general plans for the study lesson were all present and used. The video-recordings were subsequently given to the researchers. These recordings were then transcribed in full, time-coded and utterances were coded for specific informants. Finally, the transcripts in full were verified by a researcher from TasS, in addition to the original transcriber, in order to ensure their accuracy. In addition to the video material, the produced materials (e.g. teaching plans, CoRes and PowerPoint presentations) were also collected.

Method of analysis

The method of analysis chosen for this research was deductive content analysis using an unconstrained coding matrix (Elo & Kyngäs, 2008). This method uses the strengths of both deductive and inductive methods. Firstly (deductively), this research used Magnusson et al.'s (1999, p. 99) model, shown in Figure 1, as a basis for creating the main categories presented in Table 1 'Coding matrix for main and sub-coding categories'. The overarching category was not included since it would be difficult to distinguish it from the other four categories in this kind of study. One needs to bear in mind that the overarching category both influences and is influenced by these four categories (Magnusson et al., 1999). Therefore, the choice was made in the current research not to include the overarching category, a choice also made by other researchers within the field (e.g. Kellner, Gullberg, Attorps, Thorén, & Tärneberg, 2010; Park & Oliver, 2008). Each of the four main coding categories was then divided into four sub-coding categories (A1-4, B1-4, C1-4 and D1-4), also presented in Table 1. Originally, these categories were built on the descriptions presented by Magnusson et al. (1999), but were further developed using Lannin et. al.'s (2013, p. 9) descriptions, which are also based on Magnusson et al. (1999). The four main categories were divided into 16 sub-categories because of the need to be able to specify the pre-service teachers' focus more than would be the case in the four broad initial main categories.

Secondly (inductively), the initial coding matrix was developed further by considering mutually exclusive categories and coverage of the data. This was done by comparing the data with the prior coding to ensure reliability and validity. One full transcript was then coded in Nvivo (2014). This was subsequently used as an example of the developed categories, and was then discussed with a second researcher. In the light of these discussions, the sub-codes were changed and clarifications of the definitions were made, subsequently changing the initial coding. The second researcher then coded a new piece of the material, enabling the researchers to make an inter-coder reliability test in NVivo. The percentage agreement was an average of 91.4%, with all sub-codes over 80% except C4. This constitutes a high and acceptable result even by conservative standards (Neuendorf, 2002). However, to ensure research reliability for all the sub-codes, the material was studied afterwards and corrected with specific focus on the sub-code C4. The final coding is presented in Table 1, 'Coding matrix for main and sub-coding categories'.

Table 1: Coding matrix for main and sub-coding categories

Main coding categories	Sub Coding Categories
A - Display of Knowledge of Curriculum in Physics	A1. Goals for instruction - What do they intend the pupils to learn about this idea?
	A2. National, state, and or local standards.
	A3. Resources and content of textbooks (i.e. specific knowledge of things included in curricular materials).
	A4. Scope and sequencing of Physics topics - How are things connected in the curriculum? Where did it come from? Where is it going?
B - Display of Knowledge of Pupils' Understandings within Physics	B1. Prior knowledge - What have they learned in prior lessons or years?
	B2. Motivators, difficulties - When do they find certain concepts motivating or demotivating, easy or hard to understand?
	B3. Misconceptions (i.e. random mistakes, alternative conceptions, intuitive ideas, misconceptions).

	B4. Strategies pupils use to approach, solve and understand a concept or problem.
C - Display of Knowledge of Instructional Strategies for Physics	C1. Pupils' behavior that could influence teacher's way of instructing.
	C2. Discussion of best representations and actions to use for specific content (i.e. specific models or ways of presenting an idea).
	C3. Elaborating on specific activities, measures and materials to use for Physics content.
	C4. How to organize and sequence instruction and observations for specific content.
D - Display of Knowledge of Assessment for Physics	D1. Purposes and reasons for assessment - what do we want to find out and what are the reasons behind this?
	D2. Varied, best strategies and challenges for assessment - Discussion of different strategies and challenges entailed in choosing one.
	D3. Specific method, material and placement of assessment for content - elicitation process, including challenges, materials and when to do it.
	D4. Hypothesis about pupil thought patterns, responses and potential teacher responses - how they as teachers will use and respond to the collected assessment knowledge.
Other	Data that clearly does not fit into any of the four main categories.

The coding of the planning sessions was carried out in NVivo (2014) by using the following rules. First, a whole segment of utterances and single sentences were assigned to a main category in a few cases, and subsequently to a sub-category. The whole document was coded. Pauses due to interruptions and other occurrences clearly not related to the planning session were coded in the category 'Other'. The percentage reported in each sub-coding category was calculated from the total number of words in the specific transcript, divided by the number of words coded to each specific sub-category. This was done so that transcripts of different lengths could be compared. The main category results were then calculated from aggregated sub-category results.

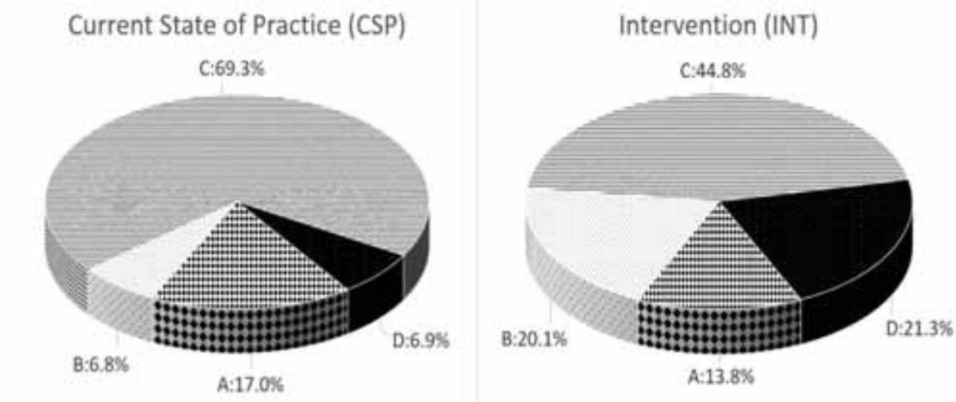
Limitations

The use of the described method leads to certain limitations with the material that are important to discuss. First this study only considers the first planning session in a sequence; other information could possibly result from further investigations. Second, the research is based on data from groups, which means that one cannot say anything about the individuals within those groups. Third, the coding does not consider the quality of the content. Therefore, the results can only show changes in focus and not, for instance, why focus has changed or the depth of understanding pre-service teachers' might have as a consequence of change. Fourth, the data is taken from a relatively small sample of research subjects who are different in the two settings, thereby making generalizations impossible. However, the issue of transference is supported by the fact that a comparison within the two CSP groups and the two INT groups shows that they have identical patterns of focus. Furthermore, the focus found within both groups is the same as that reported in previous research.

Results from comparison of pre-lesson mentoring sessions

The following compares the first pre-lesson mentoring session for Physics in CSP with that of the INT. In the first part, 'Main category results', the general tendencies found within the four distinctive PCK base categories are presented. In the second part, 'Sub-categories results', the four base categories are expanded by comparing the sub-categories.

Main category results: Presentation of tendencies found within the four distinctive PCK base categories.



- A - Display of Knowledge of Curriculum in Physics
- B - Display of Knowledge of Pupils' Understandings within Physics
- C - Display of Knowledge of Instructional Strategies for Physics
- D - Display of Knowledge of Assessment of Physics

Figure 4: Percentage division of the four main categories within PCK for science

As seen in Figure 4, 'Percentage division of the four main categories within PCK for science', the Current State of Practice (CSP) has a main focus on 'C - Knowledge of Instructional Strategies' and 'A - Knowledge of Curriculum in Physics'. In contrast, the four categories from the Intervention (INT) are focused more uniformly on all of the four PCK categories.

Sub-category results: Comparison of the sub-categories from each of the four PCK bases.

<u>Display of Knowledge of Curriculum in Physics</u>

Table 2, 'Display of Knowledge of Curriculum in Physics', gives the impression that not much has changed when comparing the CSP and INT main category 'A - Display of Knowledge of Curriculum in Physics'. However, when one takes a closer look at the numbers for the sub-categories, another perspective emerges.

Table 2: Display of Knowledge of Curriculum in Physics

Main category A: Display of Knowledge of Curriculum in Physics	**CSP 17.0%**	**INT 13.8%**
A1 - Goals for instruction - What do they intend the pupils to learn about this idea?	1.7%	9.2%
A2 - National, state, and or local standards.	5.1%	1.3%
A3 - Resources and content of textbooks (i.e. specific knowledge of things included in curricular materials).	9.8%	0.0%
A4 - Scope and sequencing of Physics topics - How are things connected in the curriculum? Where did it come from? Where is it going?	0.4%	3.3%

In the CSP, the main focus is on ‘A2 - National, state, and or local standards’ and ‘A3 - Resources and content of textbooks’. In contrast, the main focus in the INT is on ‘A1 - Goals for instruction’ and ‘A4 - Scope and sequencing of Physics topics’. This shows that even if the main category percentage is fairly stable, a shift in focus has occurred.

Display of Knowledge of Pupils’ Understandings within Physics

In Table 3 ‘Display of Knowledge of Pupils’ Understandings within Physics’, the overall percentage of the INT is almost three times greater than in the CSP, thus bringing ‘knowledge of the pupils’ understanding’ much more into focus.

Table 3: Display of Knowledge of Pupils’ Understandings within Physics

Main category B: Display of Knowledge of Pupils’ Understandings within Physics	**CSP 6.8%**	**INT 20.1%**
B1 - Prior knowledge - What have they learned in prior lessons or years?	4.0%	1.4%
B2 - Motivators, difficulties - When do they find certain concepts motivating or demotivating, easy or hard to understand?	2.3%	13.2%
B3 - Misconceptions (i.e. random mistakes, alternative conceptions, intuitive ideas, misconceptions).	0.5%	4.5%
B4 - Strategies pupils use to approach, solve and understand a concept or problem.	0.0%	1.1%

In the CSP, the main concern is on ‘B1 - Prior knowledge’ and partly on ‘B2 - Motivators, difficulties''. In contrast, the main concern in the INT is on ‘B2 - Motivators, difficulties’, where ‘B1 – Prior knowledge’ is less emphasized. However, the INT additionally focuses on both ‘B3 - Misconceptions’ and ‘B4 - Strategies pupils use to approach, solve and understand a concept or problem’, which is virtually absent in the CSP.

Display of Knowledge of Instructional Strategies for Physics

Table 4 ‘Display of Knowledge of Instructional Strategies for Physics’ shows that overall there was a 24.5% drop from the CSP to INT.

Table 4: Display of Knowledge of Instructional Strategies for Physics

Main category C: Display of Knowledge of Instructional Strategies for Physics	**CSP 69.3%**	**INT 44.8%**
C1 - Pupil behavior that could influence teacher’s way of instructing.	0.8%	5.5%
C2 - Discussion of best representations and actions to use for specific content (i.e. specific models or ways of presenting an idea).	5.3%	5.7%
C3 - Elaborating on specific activities, measures and materials to use for Physics content.	30.6%	16.4%
C4 - How to organize and sequence instruction and observations for specific content.	32.6%	17.2%

In both the CSP and INT, the main concern lies with ‘C3 - Elaborating on specific activities’ and ‘C4 - How to organize and sequence’ instruction for Physics. These two concerns permeate both the CSP and the INT. However, in the INT, they are half of what is found in the CSP. ‘C2 - Discussion of best representations and actions’ is at the same level in both contexts. ‘C1 - Pupil behavior’ has changed from 0.8% during the CSP to 5.5% in the INT.

Display of Knowledge of Assessment of Physics

Table 5 ‘Display of Knowledge of Assessment of Physics’ shows that the overall percentages of this category have generally increased threefold in the INT compared to the CSP, meaning that emphasis on assessment of Physics has considerably increased during the INT.

Table 5: Display of Knowledge of Assessment of Physics

Main category D: Display of Knowledge of Assessment of Physics	**CSP 6.9%**	**INT 21.3%**
D1 - Purposes and reasons for assessment - what do we want to find out and what are the reasons behind this?	0.0%	3.4%
D2 – Varied and best strategies and challenges of assessment - discussion of different strategies and challenges entailed in choosing one.	0.0%	1.3%
D3 - Specific method, material and placement of assessment of content - elicitation process, including challenges, materials and when to do it.	6.6%	11.5%
D4. Hypothesis about pupil thought patterns, responses and potential teacher responses - how they as teachers will use and respond to the collected assessment knowledge.	0.4%	5.2%

In the CSP, almost the only concern discussed is the 'D3 - Specific method, material and placement of assessment', while the other three categories are almost totally absent. The INT has the same main focus, albeit almost double the percentage compared to the CSP. Furthermore, the INT also includes a focus on the three other categories: 'D1 - Purposes and reasons', 'D2 - Varied, best strategies and challenges' and 'D4 - Hypothesis about pupil thought patterns'.

Discussion

Firstly, the main category findings will be discussed in order to show differences between the Current State of Practice (CSP) and the Intervention (INT). Secondly, the sub-category findings are considered and used to expand the perspectives found from the main category findings. Finally, conclusions about the implications of the results are drawn.

The main category results from the CSP (Figure 4) show that the pre-service teachers' main concern when planning a lesson was on *Instructional strategies*, combined with concerns about the use of *Curriculum*, thereby downplaying the importance of both *Knowledge about pupil understanding* and *Assessment*. Other researchers who have found the same tendency attribute it to a general focus on classroom management and survival concerns. (Bradbury & Koballa, 2007; Gess-Newsome & Lederman, 1999; Kagan, 1992; Weiland et al., 2010). This focus indicates that the preparation of the lessons occurred in quite a rudimentary manner, disregarding or downplaying many important teaching concerns when planning. In contrast, the main findings from the INT show a much more uniform focus on all of the four main categories. The reason for this more uniform focus was that *Instructional strategies* and *Curriculum* received less focus, while there was much greater focus on *Pupils understanding* and *Assessment*. These figures give credence to prior claims that both LS and CoRe can direct teachers to focus on a more learner-centred approach to planning (C. Fernandez & Yoshida, 2004; Nilsson & Loughran, 2011). Furthermore, the categories *Pupils understanding* and *Assessment* cover theoretical aspects from both pedagogy and subject content, whereas *Instructional strategies* and *Curriculum* do so to a much lesser degree. This focus implies that theory from teacher education was given more attention during the INT than the CSP. This increased focus on theoretical elements could give the pre-service teachers a better chance to start bridging the theory-practice divide (Gess-Newsome & Lederman, 1999; Loughran et al., 2008).

The results of the sub-categories within *Curriculum* (Table 2) show that the main focus for the CSP was on *National standards* and *Resources and textbooks,* leaving little focus on both *Goals for instruction* and *Scope and sequencing of Physics topics*. The two main focus areas were both related to basic teaching concerns: ‘Which books or material do I need to use?’ and ‘Which national goals are achieved using these?’ The results also show that focus on teaching goals for the pupils was downplayed during the planning process, a tendency also found in other studies (Bradbury & Koballa, 2007; Skagen, 2000). On the other hand, the INT group’s main focus was on *Goals for Instruction* and *Scope and Sequencing*, with little focus on *National standards* and *Resources and textbooks.* This shows greater focus on a learner-centred approach: ‘What do I want them to learn?’ and ‘How is this connected to the sequencing of Physics topics?’, a trend also supported by prior LS and CoRe research (Bradbury & Koballa, 2007; C. Fernandez & Yoshida, 2004). The increased focus on *Goals for Instruction* and *Scope and Sequencing*, both of which are connected to theoretical knowledge about disciplinary content, could possibly contribute to the bridging of the theory-practice gap (Gess-Newsome & Lederman, 1999; Loughran et al., 2008).

When considering the sub-categories within *Pupils' understanding* (Table 3), one finds that these categories was three times greater during the INT than in the CSP, thus emphasizing a much greater focus on categories covering the learners and their understanding of Physics. This can arguably be attributed to the use of LS and CoRe, in which pupils' understanding was given special focus (C. Fernandez & Yoshida, 2004; Nilsson & Loughran, 2011). The main focus of the CSP group in this category was on *Prior knowledge* and *Motivators*, with little focus on *Misconceptions* and none on *Strategies*. The main focus in the INT was on *Motivators* and *Misconceptions*, with the addition of *Prior knowledge* and *Strategies*. This indicates that the CSP pre-service teachers focused on 'what the pupils have learned in prior lessons', which one can read directly out of the written teaching plans, whereas the INT pre-service teachers' focus was much more on the learners and their understanding of Physics. By focusing more on the learners and their understanding, one could argue that the pre-service teachers might have a better possibility to combine their theoretically-gained knowledge from teacher education about 'pupil motivators', 'misconceptions' and 'strategies', with their own experiences from prior field practice. This is something not often found during regular practice (e.g. Bradbury & Koballa, 2007). Furthermore, the INT pre-service teachers' knowledge might then be expressed and developed further through the mentoring teachers' detailed knowledge and experiences with the specific setting which is found in the LS method (Murata & Pothen, 2011). If this is the case, one possible consequence could be that the pre-service teachers would then start to perceive some of the usefulness of the theory learned in teacher education, which often is not the case (Skagen, 2000). This, in turn, would allow them to start bridging the theory-practice gap (Gess-Newsome & Lederman, 1999; Loughran et al., 2008).

A considerable difference can be found when studying the main category *Instructional strategies* (Table 4). In the CSP, 70% of all the words coded were coded within this main category, while the corresponding percentage in the INT was only 45%. This shows that the pre-service teachers focused less on basic concerns connected to general management, which is normally the main focus in mentoring sessions (Kagan, 1992). It also suggests that their focus had moved towards more theory-laden conversations for teaching, something normally receiving little attention (Gess-Newsome & Lederman, 1999; Loughran et al., 2008). Both in the CSP and INT, the main concern lies with the two sub-categories *Specific activities* and *Organizing*, which have been related to concerns about general management or basic survival (Bradbury & Koballa, 2007; Kagan, 1992). However, focus on these basic concerns in the INT was only half of what it constituted in the CSP, thereby indicating that much less overall importance was attributed to these concerns during the INT. During the INT, focus on *Pupil behavior* was also much greater than during the CSP. Together these differences indicate a more learner-centred focus during the INT than the CSP, a tendency supported by prior LS and CoRe research (C. Fernandez & Yoshida, 2004; Nilsson & Loughran, 2011). Furthermore, the difference in focus on *Pupils' behaviour* suggests that the pre-service teachers' possibly discussed educational theory more during the INT than in the CSP.

When considering the sub-categories within *Assessment* (Table 5), one finds that these had generally increased threefold in the INT compared to the CSP, showing a greatly increased focus on the assessment of Physics in the INT. This difference can arguably be attributed to the emphasis expressed in LS and CoRe on the connection between the different teaching concerns while planning, as well as focusing on the learner (C. Fernandez & Yoshida, 2004; Nilsson & Loughran, 2011). The CSP was only concerned with *Specific methods*. Although this was also the main focus during the INT, there was also focus on the other three categories: *Purposes and reasons, Varied and best strategies* and *Hypothesis about pupil thought patterns.* This indicates that the method of assessment had become more important in the INT planning process. This can arguably be attributed to the emphasis on the goals for learning expressed through LS and CoRe (C. Fernandez & Yoshida, 2004; Nilsson & Loughran, 2011). By focusing more on assessment, the pre-service teachers may have gained a more complex understanding of teaching, which is not the norm (Borko & Putnam, 1996). The four components of *Assessment* also relate directly to theoretical perspectives within pedagogy and the subject discipline. By focusing more on all of these components, the pre-service teachers were likely to have a greater chance to bridge the theory-practice divide (Gess-Newsome & Lederman, 1999; Loughran et al., 2008).

Conclusion

The results of this study show that the use of Lesson Study in combination with Content Representations, when compared to the Current State of Practice, affected the pre-service teachers' focus during the planning process in important ways. During the intervention, as opposed to the Current State of Practice, the pre-service teachers focused much more on *Pupils' understanding of Physics* and *Assessment of understanding*, while spending less time on *Instructional Strategies*. Another finding was that the pre-service teachers had a much more uniform focus on all of the main categories comprising PCK during the intervention. This arguably shows three things. First, that the pre-service teachers focused much more on categories covering concerns about pupils' learning during the intervention, which could mean that they planned with a greater focus on the learners. Second, that the combination of Lesson Study and Content Representation to some extent helped the pre-service teachers to focus more equally on all the important elements of concern for the planning of teaching, when considered from a PCK standpoint. Since PCK growth relies on developing all elements of teaching concerns, it could imply an increased developmental opportunity. Third, by focusing on all the important elements of PCK during planning, which to a larger degree than the CSP builds on theoretical elements from teacher education, they would have a better chance to start bridging the theory-practice divide (Gess-Newsome & Lederman, 1999; Loughran et al., 2008).

However, more research is needed to establish how this shift in focus permeates the cycle of learning through the lesson planning, conducting and reflecting phases during field practice. This research could be undertaken through the use of a qualitative approach, based on one or several of the PCK categories, focusing on each of the steps in the LS cycle. Further studies could also use the presented research method in two ways. One, to look into the reflection step after the taught lesson, to see if the same tendencies can be found here. Two, to upscale the number of participant in this study to verify its findings.

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Appendix G – Article 2

Juhler, M. V. (In review). The use of Lesson Study combined with Content Representation during reflection on a taught field practice lesson to develop Pedagogical Content Knowledge. *Nordina.*

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Appendix H – Article 3

Juhler, M. V., & Håland, B. (2016). The impact of lesson study and content representation on student teachers' science teaching. In B. Hallås & G. Grimsæth (Eds.), *Lesson Study i en nordisk kontekst* (pp. 195–213). Oslo: Gyldendal Akademisk.

Appendix

Appendix

The impact of Lesson Study and Content Representation on student teachers' Science teaching

Abstract

Recent research has shown that student teachers primarily focus on pedagogical strategies and classroom management during classroom instruction instead of teaching the intended subject-matter aims and focusing on the pupils' learning. The Lesson Study method and the Content Representation tool both have a specific focus on the pupils and their learning. This chapter describes and discusses an intervention during field practice, in which student teachers used these tools in combination. To illustrate the effect of this intervention, one group of student teachers were studied. The analysis focused on the student teachers' planning of the subject-matter aim "energy transfers", the transfer of the planning into practice, and their subsequent reflections. The findings suggest that the student teachers, through the intervention, seemed to focus more on the pupils' learning. Additionally, they were also able to identify their own shortcomings. The expressed shortcomings led to the conclusion that the student teachers could have benefited from having more time to go into greater depth during the planning phase of the Lesson Study intervention.

Introduction

Classroom instruction is a critical component of the educational system; some would say the most critical component (Marble, Finley, & Ferguson, 2000). However, for the learning of subject-matter to be an outcome of classroom instruction, student teachers need to understand how to adjust and refine their practices (Bransford, Brown, & Cocking, 2004). Within European teacher education, the Japanese method of Lesson Study has started to address this issue by focusing on making the pupils' learning visible (Hart, Alston, & Murata, 2011). More recently, the Content Representation form (CoRe) has placed pupils and their learning in focus within the Science subject by combining subject-matter aims with pedagogical prompts (Loughran, Berry, & Mulhall, 2012). However, we still know little of how Lesson Study and CoRe can help student teachers focus on the learners during field practice, and even less about how a combination of the two would work. This is an important object of study, since student teachers' understanding of teaching and learning plays a crucial role in connection with pupils' learning. Furthermore, we also know that student teachers most often fail to have a learner-centered focus during field practice (e.g. Hall & Smith, 2006). Recent research, however, indicates that Lesson Study combined with CoRe can help student teachers to focus on the pupils and their learning when planning and reflecting during field practice (Juhler, 2016, In review). These studies, however, do not provide information about the student teachers' reasoning when planning, conducting and reflecting on a research lesson, thus pointing to the need for additional research to be undertaken.

This chapter therefore addresses the following research question:

> *"How do student teachers of Science plan a lesson based on a chosen subject-matter aim, implement the plan and reflect on the teaching when using the Lesson Study method in combination with the Content Representation form?"*

To approach this research question, we have analyzed the first planning, teaching and reflection stage from a Lesson Study cycle, aided by CoRe. We have focused on how a group of student teachers planned to teach the subject-matter aim "energy transfers", how they managed to transform their planning into practice, and what reflections they had afterwards about the pupils' learning of the chosen subject-matter aim. Our focus is primarily on if and how the student teachers succeeded in implementing their plans and less on evaluating the success of the lesson itself.

First, this chapter will make a case for how learning can be understood, and why student teachers struggle to prepare and instruct a lesson that promotes pupils' learning. Second, we will present how Lesson Study combined with CoRe can possibly approach this problem by moving the focus from the teacher to the learner. Third, the research design of the intervention will be described, and the results will be presented and discussed in the light of the theoretical framework. Finally, conclusions will be drawn and recommendations made for future research and implementation.

Planning and instructing for pupils' learning

One way of describing learning is to look at it as the combination of *retention*, i.e. the process of memorizing facts or producers, and *transfer*, i.e. the ability to use the information in a variety of new situations (Mayer, 2002). Most student teachers would agree that these aspects are important for pupils' learning processes. However, a frequent discovery is that student teachers do not fully manage to incorporate their beliefs into their actual classroom practices (Van Driel, Verloop, & De Vos, 1998). One reason for this is that their beliefs are often inconsistent. Another is that they generally lack deep subject-matter knowledge, thus making it hard for them to make choices about instruction (Harlen, 1997; Van Driel et al., 1998). To compensate for this, they often end up following the textbooks closely when planning, from which they pick "activities that work". They then assume that these activities would naturally bring about the intended learning (e.g. Appleton, 2003). Additionally, they also tend to focus on their own actions, pedagogical strategies, classroom management and time management, instead of the subject-matter aim (Burn, Hagger, Mutton, & Everton, 2000; Gess-Newsome & Lederman, 1999; Weiland, Akerson, Rogers, & Pongsanon, 2010). When having to develop a lesson, student teachers find it fairly easy to construct objectives for promoting *retention*. However, it seems that they have difficulties in formulating teaching procedures aimed at promoting *transfer* (Baxter, Elder, & Glaser, 1996). While mentoring teachers could help to change this situation, their main focus also seems to be on the development of general pedagogical skills and classroom management, thus not counteracting the problem (Bradbury & Koballa, 2007).

In sum, these findings indicate that mentors and student teachers need methods and tools that can help them to focus more on preparation for instruction that promotes teaching for pupils' learning during field practice.

Lesson Study and Content Representation

This section is based on descriptions found in Fernández and Yoshida (2004) and Lewis and Tsuchida (1999). Lesson Study is a research-based method that centers on the development and teaching of a research lesson as a means for groups of teachers to study questions concerning their own teaching. The research question often has a strong connection to a teaching problem, involving how to get the pupils to learn a specific teaching aim, while at the same time focusing on making the pupils' learning visible. Therefore, teachers first need to define the goal of the Lesson Study during the planning process in terms of the pupils' learning aim for the topic in question. They then have to plan learning activities that promote the pupils' learning of the aim, which they do through intensive and thorough instructional material research called *kyozaikenkyu*.

This material research goes well beyond looking at the local textbooks. The teachers, for instance, compare how different materials treat the same subject. They find out what the current research says about the teaching and learning of the topic. This often includes gathering knowledge about pupils' prior learning within the subject area to be taught so that they can anticipate pupils' reactions and solutions. It also includes knowledge of elements that can make the pupils' learning become visible in the classroom, so that they can assess this learning. Building on this information, the teachers design the lesson as a group, and one of them is chosen to teach it. Those who do not teach the lesson gather observational data throughout the taught lesson. The aim is to be able to use the collected observations to corroborate or disprove the decisions and hypothesis made during the planning stage. Finally, all the gathered data has to be scrutinized in order to assess how the learning took place. At this stage, interpretation of student responses is a key. This interpretation, in turn, is used to make informed decisions about how to improve the developed material in order to enhance learning. The lesson is then repeated, reflected upon again, and the findings are finally disseminated.

Recent research has, however, revealed that newcomers to Lesson Study do not seem to focus enough and go into enough depth during the *kyozaikenkyu* (Hart et al., 2011). Some reasons for this have been presented above. Therefore, it seems reasonable to assume that newcomers need a tool to help them to scaffold this difficult process. The CoRe form (see Figure 1) is a tool that seems to be able to achieve exactly this (Nilsson & Loughran, 2011). This form, like the Lesson Study method, draws special attention to teachers' awareness of the learner and how this awareness can influence the teaching aimed at learning the specific subject matter. The difference is, however, that CoRe does so in a much more structured and specific way. The CoRe form first challenges the teachers' thinking about teaching a Science topic, based on the recognition of the "big ideas" for that topic (Row 1, Column 2 & 3). "Big ideas" are understood as those that a teacher considers to be at the heart of learning a specific Science topic for a particular class under consideration (Mulhall, Berry, & Loughran, 2003). These "Big ideas" are then mapped against pedagogical prompts (Column 1, Rows 2 to 9), ensuring the linkage between the "why" and "what" of the content to be taught with the pupils who are to learn that content in the form of propositions (Mulhall et al., 2003). This means that if one was to decide how to choose a specific activity to teach "big idea A" (Column 1, Row 8), considerations obtained from all of the other pedagogical prompts would then have to influence this choice. In this way, choices become informed and related while building on a broad array of professional concerns. Furthermore, this structure also helps teachers to voice their normally found tacit held knowledge and beliefs about teaching for learning (Loughran et al., 2012).

Content: Age of children:	Big Idea A	Big Idea B
What you intend the pupils to learn about this idea.		
Why it is important for the students to know this.		
What else you know about this idea (that you do not intend students to know yet).		
Difficulties/limitations connected with teaching this idea.		
Knowledge about students' thinking which influences your teaching of this idea.		
Other factors that influence your teaching of this idea.		
Teaching procedures (and particular reasons for using these to engage with this idea).		
Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses).		

Figure 1: Content Representation form (Loughran, Berry, & Mulhall, 2006)

Research design and method

Data collection

This study is a part of a larger project called Teachers as Students (TasS, 2012-2015), which focuses on the subject areas of English, Physical Education, Mathematics and Science. The current research specifically addresses the area of Physics as a subset of Science, since this was the subject taught during the field practice period in question. The TasS study collected data on a control group in 2012, and data on the intervention, consisting of the implementation and use of Lesson Study, in 2013. However, this project added the use of the CoRe to Physics during the intervention. The intervention was carried out during field practice and applied to both student teachers and mentor teachers.
The participants for the intervention year came from a group of 35 possible student teachers of Science enrolled that year. Although we strongly recommended the project to the students, only a sufficient number of them volunteered to establish two groups, one consisting of four and the other of three student teachers. Each group was attached to a mentor teacher who had agreed to become part of the project. Only one of the two groups involved was chosen for this particular study. This group was chosen because their mentor teacher was especially interested in and motivated to participate in the intervention. The chosen group were in their third year of Norwegian teacher education, focusing on teaching grades 1-7. At the time of the data collection, they had not yet received their training in Physics.

A full Lesson Study cycle usually consists of the planning, implementation and reflection on two consecutive research lessons. The chosen data for the current study is from the first research lesson.
Prior to this intervention, the Lesson Study method and the CoRe tool had been introduced to both the student teachers and their mentors. General theory and practical examples about Lesson Study and CoRe had been presented to them and discussed. Additional reading on Lesson Study and CoRe was made available, as well as a draft version of a Handbook in Lesson Study that has now been elaborated upon and published (Munthe, Helgevold, & Bjuland, 2015). For practice purposes, the two authors and the two mentor teachers

together filled in a CoRe form for energy in detail. This form had a somewhat different focus from the one filled in by the student teachers.

Method of analysis

The available material for the present study is comprehensive. It consists of video recordings of the pre-lesson mentoring (planning) session, the teaching session, and the post-lesson mentoring (reflection) session. It also incorporates the initial Lesson study plan and the filled in CoRe form from the chosen group. The study only allows for focus on a few aspects. In order to narrow the scope, we applied a stepwise approach to the analysis (Boeije, 2009). First, we studied the initial Lesson Study plan and the CoRe form, describing a lesson on energy for a 7^{th} grade class, in order to gain an understanding of the lesson. We subsequently studied the pre-mentoring session, where additional aspects relevant to the CoRe emerged. The authors added these as an extension to the CoRe.

The extended CoRe and the Lesson Study plan showed which big ideas and which pedagogical consideration the student teachers wanted to focus on. However, Juhler (2016) had shown that the student teacher, when using CoRe and Lesson Study, focused more on the pupils and their learning. As the present study aims to investigate the reasons behind this focus on the pupils and their learning (see the research question of the study above), we were searching the CoRe plans for the areas that could best illustrate this. We found that the most promising area was the problem of teaching the first big idea “energy transfers” since the first big idea acts as a gateway to understanding the subsequent ones. In connection with the first big idea, our attention was drawn to four specific areas of the student teachers’ descriptions of the pedagogical prompts in the CoRe. The first was the problem of how to teach the big idea “energy transfers”, as connected to three selected activities: “Newton´s cradle”, “Rubbing of hands” and “Shooting with a catapult”. Second was the need to “Stress terms and concepts” throughout the lesson to make the pupils understand “energy transfers”. Third was the “assessment” of the subject-matter aim. The fourth and final area was the achievement of “pedagogical goals”.

We decided to use the two first focus areas as codes, from which a deductive coding was carried out (Elo & Kyngäs, 2008). The two last pedagogical concerns are covered elsewhere due to space limitations in the present chapter.

The coding covered verified transcriptions of the pre-mentoring lesson, the teaching of the three above-mentioned activities, and the post-mentoring session. The coding was initially carried out by the first author using NVivo (2014) as a tool. It was then checked by the second author and revised. From the results of the coding process, the first author identified especially interesting parts and used these to create the descriptions presented in the results section. To ensure reliability of the material, the second author checked these descriptions, comparing them to the initial coding, which resulted in revisions being made. Both authors agreed that the final descriptions presented depicted the group's thoughts in an accurate way.

It is important to note that the aim is to present these descriptions in a neutral way by limiting the authors' possible impact on the data. Therefore, the descriptions presented in the results section are based on the student teachers' expressed knowledge, as shown through their intentions and understanding. Furthermore, the interpretations presented in the discussion build on research connected to Lesson Study and CoRe, thus making the intervention the frame of reference.

Results

The following presents a three-part analysis: 1) The student teachers' planning (P). 2) The actual teaching of the research lesson (T). 3) The reflections after having taught the research lesson (R). The analysis is built on statements from the student teachers and the mentor teacher, labeled with a statement number followed by a label for the speaker (M for mentor and S1 to S4 for the different student teachers). A statement is a minimum of one full sentence.

In the description, there are references to three activities. The first is Catapult (Figure 2). Here the student teachers shoot with a rubber band in two different attachment points on the throwing arm of the catapult; with a higher attachment point, more elastic potential energy will be stored when drawn back. The second is Newton's cradle (Figure 3). In this activity, the student teachers first draw out one ball and release it so that it hits the four others (as shown in Figure 3) – one ball goes out on the other side. The second time, they draw out two balls and release – two balls go out on the other side. The third time, they draw out three balls and release – three balls go out on the other side. The third and final activity is the rubbing of hands (Figure 4). The student teachers forcefully rub two hands against each other, thereby creating sound and heat.

Figure 2: Catapult

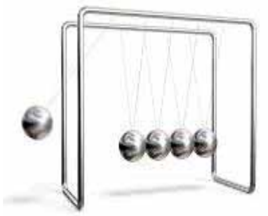

Figure 3: Newton's cradle

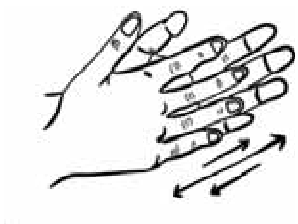

Figure 4: Rubbing of hands

Planning the lesson: What do the pupils have to learn and how to achieve it?

During the planning session and in the CoRe, the student teachers clearly stated that they wanted the pupils to learn the subject-matter aims (big ideas): "transfer of energy", "energy chains" and "energy is not created or disappearing". Student 4 summarized the approach to helping the pupils to learn the three subject-matter aims as follows: "P*17 S4: We want the pupils to understand… that energy is not created or disappearing, but instead transferred. One way of teaching this is to teach them about energy chains. To make them understand that energy transfers through chains, since they are connected"*.

To teach this knowledge, the student teachers chose the afore-mentioned three activities: "Newton's cradle", "Rubbing of hands" and "Catapult". However, there is no evidence that reveals why these three activities were considered to be the best for teaching the subject-matter aim. Nor were there discussions about comparisons to possible alternative activities that the student teachers had considered using. However, there were indications of how they considered that the three activities contributed to the pupils' learning of the subject-matter aim, as shown in the following two excerpts:

Rubbing hand activity: *"P104 S4: We think that they are going to understand that everything is (comes from) food. Then I think that most of them know that food is chemical energy. And when we start with that, then they understand that energy does not start with (rubbing her hands)… P100 S4: I also think that they will understand kinetic energy. And if it gets warm… then it has to be thermal energy"*. Catapult activity: *"106 S1: And when we take that rubber band… and pull it a long way back… P107/109 S3: Then it is potential* *energy and it thus becomes kinetic energy because it continues in the material that we shoot with… and then there is thermal and sound energy (when the ball hits the floor)”*.

These short extracts indicate that the student teachers were able to express how learning was connected to the activities, and that learning means to be able to use the specific concepts connected to energy (e.g. kinetic, potential, thermal, etc.), as used before and after an energy transfer has occurred. However, we found no instances in the analyzed material where the student teachers discussed how the energy was actually transferred, or how one energy type was being converted into another, simply that it is.

Arguably, this is why the student teachers, as illustrated in the following examples, also considered it important to emphasize these concepts in all aspects of the lesson in order to help the pupils learn.*“P106 S1: We also have to emphasize the concepts all the way through (the lesson)”*, by*”P106 S1: repeating what it means (the concepts) once again”*, *“P270 S2: Use the concepts consciously… be explicit and accurate with the use of language”*, *“P136 S4: write them up (on the blackboard) for instance”* and *“P90 S1: Actively assist them (when writing/explaining). But that word there means the same as this”*. By doing so, they express that then: *“P97 S2: it will be quite easy for the pupils to understand”*

In sum, what the student teachers expressed about pupils learning the concept of energy transfer was that they had to understand the technical concepts used to describe the energy situation before and after an energy transfer had occurred, and that energy was somehow transferred from one kind of energy to another. Furthermore, they believed that learning would naturally occur through the combination of the chosen activities and through emphasizing the concepts.

Teaching the subject-matter aim “energy transfers”: Excerpts from the Catapult activity

The first part of the lesson, lasting about 10 minutes, was used to see a short film reviewing the different forms of energy taught in the prior lesson. In the next part, lasting about 25 minutes, one of the student teachers demonstrated the three activities: “Newton’s cradle”, “Rubbing hands” and the “Catapult”. In the rest of the lesson, the pupils solved different written tasks, both individually and in groups. Due to poor recording, it was difficult to obtain the pupils' answers. These have instead been transcribed with "pupil answer".

The following example focuses on how the student teachers taught the technical concepts and energy transference. The excerpt is taken from the Catapult activity, where the student teachers demonstrate and mainly focus on the length a catapult can throw a projectile (see Figure 2).

> *"T76 S2: So if I am taking it slack (putting the rubber band on the nail furthest down the throwing arm), do you think that the projectile will fly far or… maybe it'll just fall straight onto the floor? Or isn't the catapult working then? Do you think the projectile has energy (showing the projectile)? (Several hands in the air. Placing the projectile in the basket attached to the end of the throwing arm). And when it is placed there?* (Pupil answer). *T77 S2: Yes, the projectile has potential energy. T78 S2: And if the rubber band is slack, do you think that the projectile will fly far or short? (Hands in the air). Do you think that there is little or much energy? Then I want you to write down what you think. You can talk in pairs if you are uncertain, that's all right… And then you can write what you think if the rubber band is stretched. Will the projectile go further then? Or maybe it will go higher? Is there more energy, less energy? Do I only use potential energy or do I also use other types of energy? Write what you think.*

After the pupils have written down their ideas, the teacher demonstrates what happens.

> *T79 S2: (Shoots first time with a slack rubber band – flies a short distance. Then, moving the rubber band up to the third nail on the throwing arm, stretching it more, it flies a long distance). Why did it do that? Do you think there was any difference in the energy?* (Pupil answers). *T83 S2: Yes, like x & y said, the ball will get more speed when the rubber band contracts. What was the difference in energy? Is it easier or harder to have a more or less stretched rubber band?* (Pupil answer) *T85 S2: I obviously used more energy when I had to pull the rubber band further. So, I transferred my energy to the rubber band, which again transfers it to the catapult, and again when the projectile hits the floor".*

This excerpt shows that S2 did mention the technical concepts that the student teachers wanted to emphasize. However, S2 only talked about energy most of the time, without specifying the type of energy actually occurring. This was the pattern throughout the lesson. Furthermore, there were no instances of explaining the different concepts, e.g. what does "thermal energy" really mean. There was neither any explanation of how one energy form is converted into another – just that it is.

Reflections after the lesson

After the lesson, the general view expressed was that the lesson was quite successful in terms of fulfilling the learning aim. *"R12 S1: I think that it went very well. S2 managed to convey what was necessary in connection with the activities. I think that the learning aim for most pupils was fulfilled"*. However, there were also concerns about whether some of the pupils had understood the technical concepts they had to use in their explanations, resulting in the need to spend more time on this. *"R51 S2: If they have to use the technical concepts when talking about transfer (of energy) and they do not understand what potential energy is, then it is hard, then you have to spend time on it"*. They also agreed that they should have talked in more detail when teaching: *"R312 S1: And then (instead) choose one experiment and talk it through in detail, making sure that they have actually understood it and filling in the form"*. They also agreed that they should have thought about what a correct answer from a pupil might look like: *"R116 S4: And think through what a correct answer would sound like"*, and what a correct definition might be: R*98 S4: But I do not think that we had carefully considered what the pupils were supposed to write there. There should have been a correct sentence or a definition, actually."* The latter became clear to them in view of the fact that many pupils failed to fill the summary column on a hypothesis form handed out to them.

In sum, the student teachers generally considered the teaching of the learning aim "energy transfers" to be successful. However, they also perceived the need to spend more time on the concepts, to be more detailed when explaining concepts, and for the need to have a clear understanding of what a correct definition of the concepts might sound like.

Discussion

The findings from the planning phase show that the student teachers managed to provide clear learning aims of subject-matter. This can arguably be attributed to filling in the CoRe form, and shows a positive contrast to that of normal practice (Appleton, 2003). They also managed to select three activities through which to teach this subject-matter aim, although without discussing why these activities were the most suitable. This arguably shows a weak link between the subject-matter aim and the chosen activities, which suggests that the activities were chosen because they were "activities that work" (Appleton, 2003). If "activities that work" become instructional units for learning, teachers do not need to think deeply about the connection between an activity and its subject-matter aim. One reason for this week link might be that the student teachers' content knowledge background was poor (Harlen, 1997), due to their educational status. The result was that they struggled to express how the subject-matter aim was specifically connected to the activities.

If the latter finding is true, we consider that the task of formulating teaching objectives, aimed at promoting *transfer*, becomes even more difficult than is normally the case (Baxter et al., 1996). Therefore, the student teachers arguably end up describing learning as meaning little more than being able to reproduce and use the specific concepts when writing and talking about the activities (P104, P100, P106, P107, P109, P270, P136, P90). One could argue that they actually believe in this way of teaching for learning, which mostly resembles that of *retention* (Mayer, 2002). However, due to the pedagogical training they have received at the university, this is an unlikely assumption. Instead, it is more likely an effect of not having gone into sufficient depth during the *kyozaikenkyu*.

The presented excerpts from the lesson show that the student teachers do focus on the teaching of the subject-matter aim (T76, T78, T79), although this is done in a rather imprecise manner. The student teacher often uses the concept of "energy", but without specifying the kind of energy in question (T76, T78, T79, T83, T85, T99). This is contradictory to their expressed intentions of wanting to emphasize the concepts throughout the lesson (P106, P270, P136, P90). It is therefore the case that their beliefs are at odds with their classroom practice (Van Driel et al., 1998). Furthermore, this misconnection indicates that the activities could be chosen as “activities that work” (Appleton, 2003), and that they should have gone into greater depth during the *kyozaikenkyu*.

During their reflections, the student teachers found that they should have taught the concepts in such a way that the pupils would have learned them more effectively (R51). They believed that if they had taught the experiments in more detail (R312), a more effective level of learning could have been achieved. However, in order for this to happen, they would have needed a better understanding of what a correct answer might look like (R116). The ability to define what a correct answer is, and what it might look like, mainly depends on the student teachers’ subject-matter knowledge (Loughran et al., 2012). These findings suggest that the student teachers needed more knowledge about the subject-matter aims in connection with the teaching procedures. This knowledge gap should have been addressed by filling in the CoRe form (Loughran et al., 2012) and during the planning of the Lesson Study (Fernandez & Yoshida, 2004). Therefore, these findings show the importance of spending more time and dedication to the *kyozaikenkyu* during the planning phase since, through this process, the student teachers should obtain an understanding of the subject-matter knowledge aims and their connection to the specific teaching procedures.

However, one also needs to bear in mind that the student teachers and their mentor teacher were trying them out for the first time, which arguably prevented them from fully understanding and managing all the concerns in question. This may explain why the general view expressed was that the lesson was quite successful in terms of fulfilling the learning aim (R12). Of equal importance is the fact that the findings suggest that the Lesson Study method, in combination with CoRe, enabled the student teachers to pinpoint many shortcomings. Such shortcomings normally receive little attention (Bradbury & Koballa, 2007; Juhler, In review). Furthermore, student teachers will have an opportunity to rectify these shortcomings when planning and teaching the upgraded lesson through the Lesson Study cycle (Fernandez & Yoshida, 2004).

Conclusion

From the analysis and discussions above, we have shown, contrary to earlier praxis (Appleton, 2006; Juhler, 2016), that the student teachers in the present study, through the use of Lesson Study in combination with CoRe, managed to put a good deal of work into thinking about and defining learning aims of subject-matter for their lesson, which especially revealed the impact of the CoRe. However, the findings also suggest that the learning activities used might have been chosen as “activities that work”, thereby weakening the connection between instruction and the subject-matter aim. Furthermore, the student teachers’ expressed understanding of pupils having learned the subject-matter aim, might mean little more than being able to reproduce specific concepts. The latter two findings suggest a need for more engagement with the *kyozaikenkyu*, a challenge also highlighted by other researchers (Hart et al., 2011).

During the lesson, the focus was on the subject-matter aim. However, the teaching was conducted in a rather imprecise manner. This again underlines the importance of providing more time and dedication to the *kyozaikenkyu*, thereby giving the student teachers a better understanding of the connection between the subject-matter aim and the way of teaching the activity. However, the student teachers’ reflections after having taught the lesson showed that they were able to pinpoint many of the shortcomings that occurred during the planning phase, shortcomings which normally receive little attention (Bradbury & Koballa, 2007; Juhler, In review). This finding can arguably be attributed to the use of Lesson Study combined with CoRe, but especially to the use of Lesson Study, since it challenges student teachers to teach the same lesson again in an upgraded version (Fernandez & Yoshida, 2004).

On the basis of our study, we conclude that the introduction of Lesson Study in combination with CoRe in teacher education seemed to enable the student teachers to focus more on the pupils’ learning than what is normally found. Furthermore, it also enabled them during their reflections to pinpoint shortcomings from their planning and teaching, something which normally receives little attention. However, the research also revealed several challenges that need to be addressed in further research. It would especially be interesting to look into the other pedagogical prompts presented in CoRe, as well as studying how the student teachers can better be helped to gain a deeper understanding through the *kyozaikenkyu* (i.e. through having a knowledgeable person leading the Lesson Study).

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Appendix

Appendix I – Article 4

Juhler, M. V. (In press). Assessment of understanding: Student teachers' preparation, implementation and reflection of a lesson plan for science. *Research in Science Education.*