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The Use of Lesson Study Combined with Content Representation in the Planning of Physics Lessons During Field Practice to Develop Pedagogical Content Knowledge

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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, which is a method for planning, carrying out and reflecting on a research lesson in detail with a learner and content-centered focus. This was used in combination with a second means, content representations, 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. First, they focused much more on categories concerning the learners. Second, 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

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Introduction

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 learned 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 (LS) (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 LS, since CoRe is a possible aid to those unfamiliar with the LS method. Hart et al. (2011) discovered that those who were unfamiliar with LS 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 LS 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 LS in combination with CoRe.

The stage is thus set for an intervention study, introducing both the LS 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, LS and CoRe. Specifically, it will add new knowledge about the combination of LS and CoRe. This is accomplished through addressing the following research question:

> How does the use of LS combined with CoRe 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 2 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. Second, 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 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, as depicted in Fig. 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 predates 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).

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

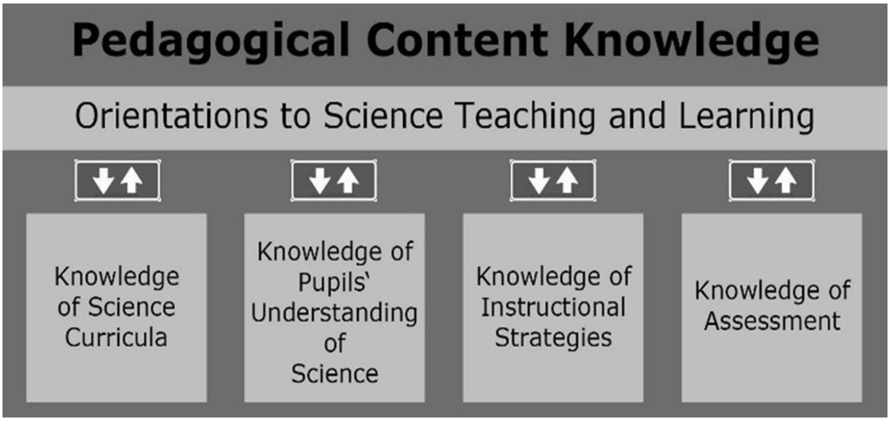


Fig. 1 Components of PCK for science teaching (Magnusson et al., 1999, p. 99)

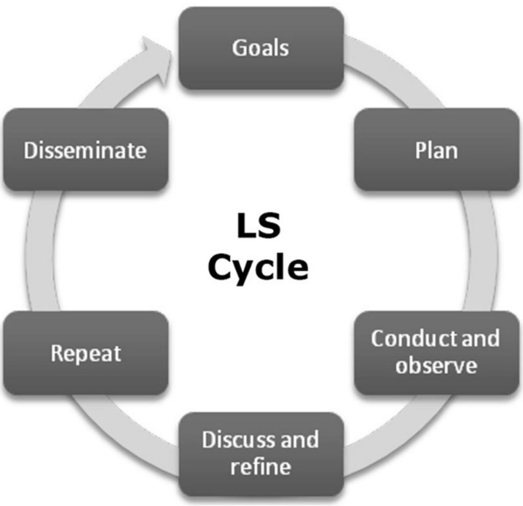
refers to knowledge about mandated goals and objectives, as well as specific curricular programs and materials. This knowledge, in turn, relates to specific topics, across topics and development over different school years. The second component, 'Knowledge of pupils' understanding of science,' refers 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 LS, in combination with the scaffolding tool CoRe, 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 USA 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 Fig. 2 (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 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

Fig. 2 Lesson study cycle (Fernández & Yoshida, 2004)



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 (Fig. 1, sub-component 1). It guides the teachers' thinking toward the pupils' perspectives, planning around different possible problems, solutions, responses and ways in which the pupils can react (Fig. 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 learned (Fig. 1, sub-component 4), which is linked to a specific way of instructing the pupils (Fig. 1, sub-component 3) (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 toward teaching change as they now design lessons that are more content-centered, learner-centered, engaging and supportive of learning, with a clear focus beyond concerns to do with basic survival and classroom management (Fernandez & Yoshida, 2004; 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 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 Fig. 3) (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).		

Fig. 3 CoRe form (Loughran et al., 2012)

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 (Fig. 1, sub-component 1) is closely linked to learning about pupils' learning (Fig. 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 (Fig. 1, sub-component 3); their concern is not only with how the activities might work, but also why (Fig. 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 toward 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 LS 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 focus on Physics and was collected as part of the aforementioned TasS project. The data were gathered over a 2-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 2 years.

The Two Conditions, Years 2012 and 2013

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 4 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 LS in combination with 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. First, the mentoring and pre-service teachers were presented with general theory on LS and CoRe. Second, they were shown examples of how these tools have been used. Finally, these examples were discussed in both groups and 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.

Participants in the Study

The participants in the study consisted of fourteen pre-service teachers and four mentoring teachers. For each of the 2 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 were collected for TasS through two cycles of planning, teaching and reflecting during field practice, a decision based on the steps in the LS cycle. The data for the current study were 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. First (deductively), this research used Magnusson et al.'s (1999, p. 99) model, as shown in Fig. 1, as a basis for creating the main categories presented in Table 1. 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.,

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 do not fit into any of the four main categories

Kellner, Gullberg, Attorps, Thorén, & Tärneberg, 2011; 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.

Second (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 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 intercoder 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 afterward and corrected with specific focus on the sub-code C4. The final coding is presented in Table 1.

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 are 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 the 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.

As shown in Fig. 4, 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.

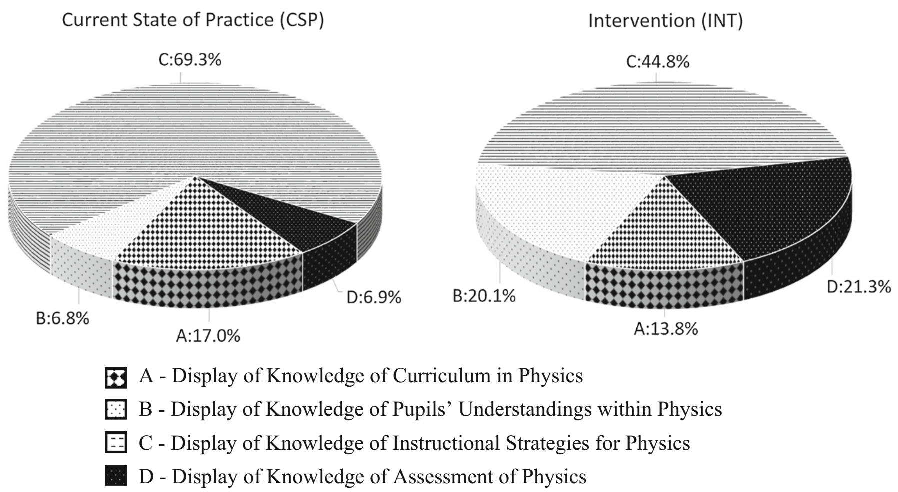


Fig. 4 Percentage division of the four main categories within PCK for science

Display of Knowledge of Curriculum in Physics

Table 2 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.

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, 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.

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.

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

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

Display of Knowledge of Instructional Strategies for Physics

Table 4 shows that overall there was a 24.5 % drop from the CSP to INT.

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 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.

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.’

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

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

Discussion

First, the main category findings will be discussed in order to show differences between the current state of practice (CSP) and the intervention (INT). Second, 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 (Fig. 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-centered approach to planning (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-centered 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; 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 (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 toward more theory-laden conversations for teaching, something normally receiving little attention (Gess-Newsome & Lederman, 1999; Loughran et al., 2008). Both in the CSP and in 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-centered focus during the INT than the CSP, a tendency supported by prior LS and CoRe research (Fernandez & Yoshida, 2004; Nilsson & Loughran, 2011). Furthermore, the difference in focus on *Pupils' behavior* 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 (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 (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 LS in combination with CoRes, 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, 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, the combination of LS and CoRe 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 whether the same tendencies can be found here, and two, to upscale the number of participant in this study to verify its findings.

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