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In-service Science Teacher Professional Development

Abstract

The aim of the present study was to explore teachers' professional development when using the tool Content Representations (CoRe) to plan a learning study in chemistry, which they also implemented and analysed. The work of six experienced science teachers, all teaching at the 6th to 9th year (age 13 to 16 years), was followed at eight group meetings during one year. The teachers' discussions during the group meetings were audio and/or video recorded. Recordings were transcribed and a thematic analysis was performed. The results show that two main approaches to teaching emerged in the teachers' discussions, a pragmatic and a reflective approach, respectively. During the investigation period, the focus of the teachers' discussions changed, from a predominantly pragmatic approach to a predominantly reflective approach. The results indicate that the work with CoRe and learning study stimulated the teachers to express and discuss their knowledge, beliefs and attitudes towards teaching, i.e. promoted their professional development.

Introduction

Swedish students are interested in science, but they do not find school science interesting (Jidesjö, Oscarsson, Karlsson, & Strömdahl, 2009). A possible consequence of this is that Swedish test results in international comparisons, such as PISA (OECD, 2013), have been declining for a period of years.

Students' declining results and interest in science was taken as starting point for a recent development project at a school in the south of Sweden. Since the teacher is one of the most important factors for students' learning (Hattie, 2009), we decided to study the teachers' professional development during this school development project.

Teacher professional development is a complex issue. In a recent review, Avalos (2011) summarize 10 years of studies on teacher professional development. Although different contextual factors interact with the outcome of a particular study, there are similarities in the process that teachers undergo in their development. Often the process starts with informal exchanges and continues with networking and peer coaching, moving from co-learning through talk to co-learning through observation. Professional learning communities that promote changes in teaching culture are characterized by collaboration between teachers that encourage sharing and reflection, and focus on student learning, teacher authority, and continuous teacher learning (Capps, Crawford, & Constas, 2012; Vescio, Ross, & Adams, 2008). A learning community is situated and the outcome of teachers' professional development depends on how well the professional learning community interacts with the teachers' every day work and makes meaning for the teachers (Clarke & Hollingsworth, 2002; Putnam & Borko, 2000; Riveros, Newton, & Burgess, 2012). As Riveros et al. (2012) points out, the introduction of a professional learning community is not the goal, but should be regarded as a tool for school development.

Different models have been suggested to describe teacher professional development (Clarke & Hollingsworth, 2002; Guskey, 1986). The interconnected model of teacher professional growth, proposed by Clarke and Hollingsworth (2002), describes four different domains (external, practice, personal and consequences) that are interconnected in a non-linear way through teachers' reflection and enactment (see Figure 1).

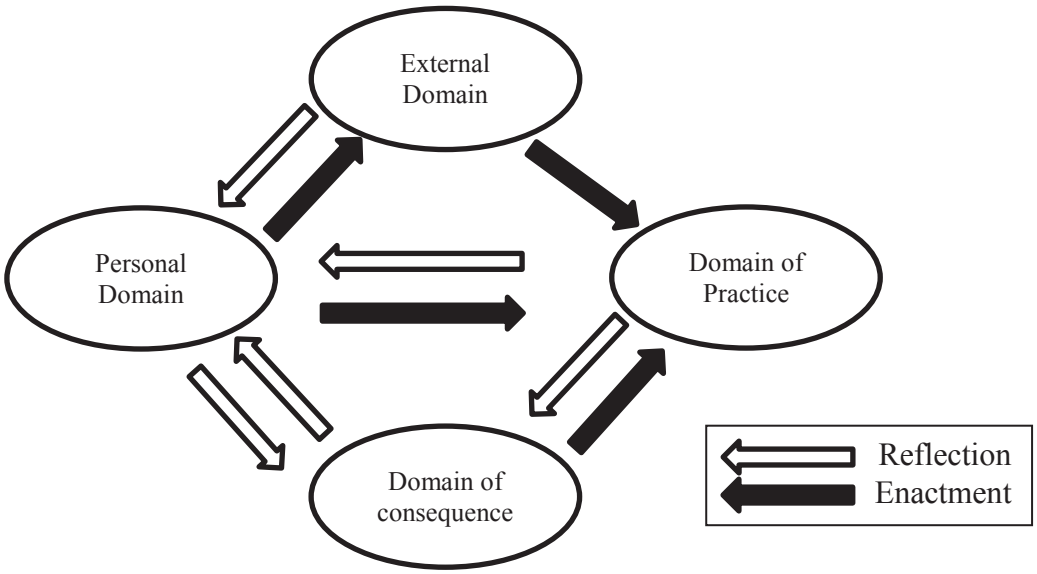

Figure 1. The interconnected model of teacher professional growth (after Clarke and Hollingsworth, 2002 p. 951).

The model identifies multiple growth patterns between the four domains, illustrating that teacher professional learning is personal and does not follow a linear pathway, as previous models have assumed. This means that teachers' professional development can take different ways for different individuals. The model distinguishes between "change sequences" and "growth network", where a growth network is when the change leads to professional development of the teacher. The model was

recently used as an analytical frame in a review of 44 studies on professional development programs (van Driel, Meirink, van Veen, & Zwart, 2012). The authors conclude that most of the studies reviewed have the characteristics that, according to the literature, are necessary for making professional development programs effective, i.e., the studies focus on a specific science content, are related to classroom activities, involve teachers in an active way, and are collective in nature.

The approach in a learning study has the potential to stimulate teacher professional development and co-learning, both through discussion and through observation (Andrew, 2012; Davies & Dunnill, 2008). A learning study builds on variation theory (Marton & Tsui, 2004) and consists of a number of stages, described in detail by Holmqvist (2011). In brief, the teachers decide on a learning object, develop a pre-test and prepare a research lesson based on the students' results on the pre-test. The research lesson is implemented by one of the teachers and video recorded, whereafter the teachers jointly analyse and revise the lesson. The revised lesson is then implemented in a new class (often by another teacher then the one that gave the first lesson) and video recorded. Often the cycle is carried out a third time, whereafter the completed learning study cycle is analysed. In a study by Pang and Ling (2012), teachers performing a learning study experienced that the variation theory made them more attentive to students' learning than previously. However, the scientific language used in variation theory may also alienate in-service teachers from embracing the theory (Gustavsson, 2008).

Science teachers' professional development can be explored by following their change in pedagogical content knowledge (PCK; Shulman, 1987). In order to get insight into teachers' PCK, Loughran, Mulhall, and Berry (2004) developed the tool Content Representations (CoRe). Briefly, CoRe uses a template to portray overviews of teachers' PCK in relation to their teaching of a specific science topic. The teachers are requested to identify the "big ideas" for the topic of interest, and then to answer questions related to pedagogy, such as: why it is important for students to know these ideas, what difficulties students may have in learning the ideas, and, how these ideas fit into the knowledge that the teacher holds about the content in question. Although CoRe is designed to be used as a method to assess teachers' PCK, CoRe offers the teachers a systematic way of planning, organizing of and reflecting on a specific topic. Thus, we suggest that a CoRe-based methodology has the potential to stimulate teacher professional development.

The aim of the present study was to explore science teachers' professional development when using a CoRe based methodology to plan and perform a learning study. The research questions were:

- What characterize the teachers' approaches to teaching?
- How do the teachers' approaches to teaching evolve during the studied period?

Material & Methods

In order to explore the teachers' professional development, a school development project was studied for one year from its onset, including a learning study based on the teachers' work with CoRe. Six experienced science teachers (4–22 years of practice) were observed during eight group meetings during the year (Table 1). All teachers were teaching at the 6th to 9th year (age 13 to 16 years) at a middle sized school in the south of Sweden.

At the meetings, the teachers followed a clear agenda, either written or introduced by a supervisor leading the meetings. At the first meeting, the teachers made a joint plan for a specific subject area, based on issues assembled by the headmaster, such as assessment, variations in teaching methods, how to support students having problems to learn science, and external resources. An external expert, who previously had made several studies based on CoRe and learning study, was invited to the second meeting. During this day, the teachers were given a lecture and worked together with a joint CoRe.

Table 1. Overview of teachers' meetings included in the study.

Meeting		Content of teachers' meetings	Time
1	October 2012	Discussions on assessment, teaching methods, how to support students, and external resources Preparation of a common lesson plan	Half a day
2	January 2013	Training day with focus on learning study and CoRe Lecture by an external expert and a work shop on CoRe	1 day
3	March 2013	Work with CoRe to plan a subject area in basic chemistry for year 6	2–2.5 hrs
4	April 2013	Continued work with CoRe to plan the subject area in basic chemistry for year 6	2–2.5 hrs
5	May 2013	Construction of a pre-test for the learning study, with focus on atoms and matter	2–2.5 hrs
6	August 2013	Analysis of pre-test and planning of the first research lesson	2–2.5 hrs
7	September 2013	Analysis of the first research lesson and post-test Planning of the second research lesson	2–2.5 hrs
8	September 2013	Analysis of the second research lesson and post-test Evaluation of the complete learning study cycle	2–2.5 hrs

After the two first meetings, the teachers met six times working with CoRe and the learning study. These meetings (meeting 3 to 8) were led by a supervisor. During meetings 3 and 4, the teachers worked with a new CoRe to explore a subject area. Basic chemistry for year 6 was chosen, and within this subject area, five "big ideas" were identified and the CoRe template was worked through (Appendix, Table 3). The big idea atoms and matter was chosen for the research lesson, and the teachers constructed a pre-test for the learning study (meeting 5). Based on the analyses of the students' answers, the teachers planned the first research lesson in the learning study cycle (meeting 6). The research lesson was given by one teacher and at meeting 7 the teachers analysed the video recording and the post-test, and planned the second research lesson. This lesson was given by the same teacher that gave the first lesson, but in another class. At the last meeting, the teachers analysed the second research lesson, after which they evaluated the completed learning study cycle.

The teachers' discussions during the eight meetings were audio and/or video recorded. Recordings were transcribed verbatim and read several times to identify themes and categories. Using an iterative process, the data was coded and categorized (Table 2) using the software NVivo, and a thematic analysis was performed following Braun and Clarke (2006). In the coding, four categories were identified, i.e., method of teaching, external factors, and didactic questions on teaching content and student learning, respectively. The first two categories contained items in which the teachers emphasized that their work would give them ideas on lesson structure, activities, and assessments, but the students' learning was implicit. The third and fourth category encompassed records in which teachers emphasized the didactic questions what, why and how, i.e., the students' learning was mainly explicit. To reveal themes, the content of all four categories were scrutinized to reveal qualitative differences in the teachers' approaches to teaching. The codes, categories and themes were refined through discussions between the authors until consensus was reached. The excerpts (teachers numbered T1–T6) presented herein were translated from Swedish by the authors.

In addition to the meetings described above, the teachers met during the autumn 2012 every second week for approximately one hour. These meetings had no given agenda and mostly dealt with practical issues. The meetings were also audio recorded, but the data was not used in the present study.

Ethical recommendations from the Swedish Research Council (Hermerén, 2011) were followed throughout the study.

Table 2. Codes, categories and themes employed in the analysis of the data.

Code	Teacher focus	Category	Theme
Task that activate students	Lecture, laboratory and assessment arrangements	Methods of teaching	Pragmatic approach
Funny tasks			
Ways to explain			
Laborations			
Methods for assessment			
Curriculum & syllabus	Factors that affect teaching	External factors	
Class & students			
Time & schedule			
Instructional material			
What	Structure Goal & purpose Content	Teaching content	Reflective approach
How			
Why			
What	Student knowledge Learning Understanding	Student learning	
How			
Why			

Results

On the basis of qualitative differences in teachers' discussions, two themes emerged; a *pragmatic* and a *reflective* approach (table 2). Taking the *pragmatic approach*, the teachers' discussions were focused on doing and activities, but their statements did not contain any arguments and did not imply explicit reflection. In the teachers' discussions, the students' learning was only implicit. In the second theme, the *reflective approach*, teachers' reflections were explicit, both with regard to teaching content and student learning. During the investigated period, the focus of teachers' discussions changed, from a *pragmatic* to a *reflective* approach. At the initial meetings, focus was mainly on practical activities, but during the study, focus changed toward reflection on content and students' learning.

Pragmatic approach

While taking the pragmatic approach, the teachers' discussions were focused on doing and activities, and they did not give any arguments or reflect explicitly on their choices. Their talk had a pragmatic and methodical approach and the student's learning was implicit in the discussions. That is, the teachers discussed how to choose the "best" method, and scientific knowledge was more or less regarded as fixed, not something that develops and changes over time. For example, when the teachers say that they found an activity or issue being fun, we have categorized these responses as pragmatic, as they do not contain any reflection on what the choices imply for the content or student learning. Two categories were identified within the pragmatic approach, i.e. *methods of teaching* and *external factors*.

Methods of teaching

This category encompasses the teachers giving practical tips and advices for lessons, labs, and assessment that can be used collectively and/or individually. The teachers did not give any arguments for why certain methods might facilitate student understanding.

The teachers gave ideas and advices on *task that activate students,* but without any arguments or reflection. At meeting 2, the teachers following the CoRe template discussed students' conceptual understanding and misconceptions of the subject and how this affects teaching. They described what they already do, but they did not reflect on the activities.

> T3: *….We have this lesson. They sit in groups and … you get a situation presented, in which something happens. And then you should highlight what conversions that occur in this situation. Just as a group discussion. It's a great exercise… (Meeting 2)*

Later, at the same meeting, the teachers also suggested practical tasks with the argument that it would be *fun* for the students, but they did not reason about why or how this task would fit into the lesson.

> T4: *I think that would be really fun indeed … you'll get the lamp to glow … here you have … you will have this and you will have this. So make it work. It would have been fun.*
> T2: *It had actually been fun. (Meeting 2)*

When the teachers discussed ways to explain that might facilitate students meaning-making and prevent misconceptions, they did not reflect on why or how these methods could facilitate the students' understanding. They emphasized the importance of using different methods and stressed the importance of teacher-centered lessons, where the teacher goes through the content slowly and repeats "facts" to facilitate student understanding.

> T4 [reading from CoRe]: *In what specific ways have you thought about facilitating their understanding and prevent confusion regarding these ideas. /…../*
> T3: *Take it slowly.*
> T4: *Slowly and repeat.*
> T3: *Repeat and just … not to cover too much at the same time. … (Meeting 2)*

External factors

The teachers found that external factors, such as the curriculum and syllabus, text books, and the national tests control and affect their teaching. Furthermore, local factors such as class size, classroom, new classes, and time, also had an influence on their teaching.

The teachers used the curriculum as an argument for their choices, for example, when they discussed why they choose a particular teaching method. By choosing this particular teaching method, the teachers claimed that they have a method to assess the students on the basis of the assessment criteria.

> T2: *At the same time there are some criteria in that direction. So we need to test it. But I'm not sure that it is the discussion competence…formulated in that way. It's about how to assimilate information and …*
> T4: *Yes to assimilate information and then you come up with your own opinions which broaden and deepen and… (Meeting 2)*

The teacher argued that the students' difficulties with the pre-test were due to factors such as *new classes* and new teachers.

T6: *Then I feel that the whole project actually might have been better to take a bit later in the semester. Now there are new classes. I have not met them before. You actually do not really know how the classes work. So this may affect. (Meeting 6)*

Time, and more specifically lack of time, was regarded as an important factor by the teachers, as illustrated by the following example.

T4: *I feel that ... we have now ... if we look at the time we have now, then it is not ... because we feel a pressure by national test and so on. (Meeting 2)*

The teachers also discussed the lack of practical exercises for the students and referred to the *instructional material* and how the textbook affects the way teacher is teaching. In the example book 1 and book 2 is used instead of the real book titles.

T3: *Finding a good textbook. Now we have for example…You had a few faults with book 2, which I think is pretty good. Book 1 I think is a bit too heavy in this area.*
T4: *I'll try. It is my goal with this term. I'll try to get away from book 1. I think it is so boring. (Meeting 2)*

The external factors were more or less taken for granted by the teachers and something they could not change. Instead, the teachers used the external factors to explain and argue for the choices they made in their teaching.

Reflective approach

In the second theme, the *reflective approach*, teachers' reflections are explicit, both on *teaching content* and on *student learning*. When reflecting on content, the teachers gave arguments for their views and/or reflected on the content and structure, e.g., why they used certain teaching methods, what they highlighted within a certain topic, and why and how they changed the content of a lesson. In their reflection on *student learning,* teachers gave motivations for and/or reflected on their views of learning. They addressed students' learning, discussed what knowledge is, how they could stimulate and facilitate student learning, and why students had difficulties. In both categories, the teachers reflected on *what*, *how* and *why*.

Teaching content

In this category, teachers discussed teaching structure, lesson content, aim and purpose. They argued for their view and/or reflected on the content and structure, as well as on students learning.

The teachers reflected on *what* content should be included in their teaching.

T2: *The question is whether we need to use those words in the sixth grade. If we still remain in the sixth grade? We do not need to get into them. Actually, neither charging nor shell. At least not shell. (Meeting 3)*

When the teachers discussed students' misconceptions, they reflected on *how* they usually teach a particular concept and how they use specific concept.

T3: *Yes but it´s funny. When we talk about the cell, we are talking about mitochondria, and there the energy is produced. I say so anyway. It might be completely wrong to say so but…*
T2: *Produced may not be completely well-chosen to say, /…/ But you sometimes need to make it simple so it is understandable.*
T3: *I say produced. You could say transform substances into energy.*

T2: *Yes or releasing energy which is in…*
T1: It's like a …
T3: *Releasing. Produce sounds wrong. (Meeting 2)*

When the teachers planned the first lesson, they reflected on *how* to design the lesson structure, e.g., if the lesson should start with a lab, or a practical task.

T5: *I'll give them something else of course. Though … you could imagine that we place all the things that are matter here, and here we place all things that "are not" matter. How much could they be able to put on the "are not" table?* (Meeting 6)

In the reflection on *why* certain content should be included or why using a certain lesson approach, the teachers' reflections also included students' learning and they reflected on why a certain lesson approach could help students make meaning of the concept "matter".

T5: *You have nothing … what would you add… you would not have anything on the "is not" table after all. That's what they really should be aware of.*
T1: *That's what they want to see.*
T5: *Whatever they come up with… (Meeting 6)*

When the teachers had analysed the first lesson and were planning the second one, they discussed if and *why* they should change the content of a demonstration.

T6: */…/ Then you might demonstrate it with water instead. Because, that is how you usually begin to show it./ …/ So, first you weigh it and then so you melt the ice and then weigh it.*
T2: *Yes, okay.*
T6: *I feel … that is usually the way I start. (Meeting 7)*

Student learning

Within this category, the teachers discussed students' previous knowledge, misconceptions, how to facilitate students' learning and understanding, and students' difficulties in learning.

The teachers reflected on *what* they consider are the goals for student learning in the teaching situation.

T2: *Precisely, and become aware of energy, in a sense. Also their use of energy.*
T3: *Exactly (Meeting 2)*

In addition, the teachers reflected on *what* students, who need more time, learn when they are not in focus of the teachers' interest.

T5: *I have a tendency to ask a question and quickly let someone to respond. Does everybody have time to think through my question? …I'm telling you … op, op … it's like this … yes, yes, yes … think it's fun … But my God, I've asked the question. I allow no one time to think. Instead, yes, yes …*
T3: *But those … those who need a little more time they are lost … thus …*
T5: *They do not get it from me … but yeah, yeah (Meeting 7)*

In a discussion on *how* and when to introduce some specific concepts, one of the teachers reflected on how they can stimulate and facilitate students' learning and understanding. In the discussions, the teachers based their reflections on their view on how students learn.

T4: *Thus I would like… I notice all too often with students that… that… The more structure you have in it. The more I go through only one thing. They know nothing else. Then I'll go through another thing and so … they know nothing else. And then you add it together. How this is related to that. And this we intend to do there and then it usually become. Oh! So … Yeah … now I put it together. Because I know this and I know that. Now, I can …summarize everything. (Meeting 3)*

In the next example, the teachers' reflected on *how* a sequence from the first research lesson can facilitate students learning.

T2: *A lovely thing you did there, I think, was … when you took the balance and said you can weigh a grain of dust on this balance.*
T6: *Mm*
T2: *And then you got a response. You got a response from the entire class. It was somehow perfect. Because then they realize that. It is certainly possible to weigh many grains of dust, but when there is so little matter, it is impossible to weigh it, at least on such a balance. (Meeting 7)*

When reflecting on *why,* students having difficulties in learning and understanding were in focus. The teachers reflected on student results in the national test and why they had difficulties even with subjects covered in lessons preceding the test.

T2: *And then you should take… I… We have worked a lot with decomposition and decomposers, and so on. But still, they have not got it. /…/ there is something to do … Being able to respond even to such a question, then. I'm not saying that everyone missed, but there is something to do. /…/ They cannot translate it into a new issue (Meeting 4)*

When analysing the first research lesson and reflecting on *why* students having difficulties in understanding, the teacher realized that when his/her focus was on implementing the lesson planning, he/she lost focus on students' learning.

T3: *Yes it's true. They cannot keep up with my thoughts. I am already one step ahead. What I will do after this. (Meeting 7)*

When reflecting *why* the students have difficulties in phase transition, the teachers identified that introduction of something new put the students focus on other things then intended by the teacher.

T6: *I think … I think when we used the metal in the six B, it became a new thing for them. So they focused on the wrong thing, I guess. … Yeah what kind of metal is it? /…/ It was too much focus on just the metal. Not on the actual phase transition… (Meeting 8)*

Teachers' approaches to teaching evolve during the studied period

During the investigated period the focus of teachers' discussions gradually changed, from a *pragmatic* to a *reflective* approach. In general, the talk in which the teachers showed a reflective approach increased in frequency between the meetings. At the initial meetings and especially at the first, focus was mainly on practical activities, such as assessment, knowledge requirement, skills, and external factors.

Gradually during the study, the character of the teachers' discussions changed and their degree of reflection increased throughout their work with the CoRe questionnaire and the learning study. The teachers still discussed practical tasks and details at the end of the study, but the didactic questions were now much more prominent. This was most obvious for the reflection "why" within the category

Student learning. At the first meeting, the teachers' did not at all reflect on students learning, but at the end of the study reflections on why students learn were frequent.

Discussion and conclusions

The aim of our study was to explore what happens with teachers' approach to teaching during a school development project when they used the tool CoRe to plan and implement a learning study. In the beginning of the study, the teachers mainly discussed practical issues without reflection, while the didactic questions what, how and why were prominent at the end of the study.

The methodology used fulfils the criteria that according to the literature stimulate teacher professional development. Together the teachers made observations and focused on student learning, factors that stimulate teachers' professional development and growth (Avalos, 2011; Vescio et al., 2008). To be a successful professional learning community, it is important to use a strategy that enables the community to identify a development area. In the present study, the work with CoRe helped the teachers to identify a development area. It is also necessary that the teachers have time for reflection on the activities that they are involved in.

According to van Driel et al. (2012), school organizational conditions and the impact of a facilitator are often not taken into consideration within professional development programs. In our study, the school development project provided a supporting environment, with time for discussions and a community of colleagues. The work with CoRe was introduced by an experienced researcher within the field and the meetings had a clear agenda and were led by a supervisor. As the teachers were colleagues at the same school and had regular meetings before the studied period, meaningful discussions started already at the first meeting. Through their discussions, teachers started to reflect on their choices and what they consider important in teaching.

Learning study is a methodology that has the potential to improve teachers' approach to teaching and their professional development through its elements of collaboration (Davies & Dunnill, 2008). In the present study, the teachers expressed that they appreciated the work to plan and implement the learning study that they found stimulating collaboration. However, to deliberately teach in this way requires practice and time, and a cycle with only two research lessons is less than commonly used (Holmqvist, 2011). The teachers in our study mainly talked about the content in the research lessons in terms of "good" or "not good", but also reflected on why students had difficulties to see the phase transitions and instead focused on other issues. Even if the teachers did not use variation theory deliberately, they reflected more explicitly on student learning after the learning study than before.

We conclude that it is likely that the work with CoRe and the learning study has stimulated the teachers to express and discuss their knowledge, beliefs and attitudes to teaching. If the work also stimulated the teachers to be more focused on student learning, as earlier found by Pang and Ling (2012) when evaluating a learning study, remains to be answered. CoRe has earlier been used as a tool to develop and explore teachers' pedagogical content knowledge (Bertram & Loughran, 2012; Nilsson & Loughran, 2012). In the present study we show that CoRe also can be used to stimulate teachers' professional development and growth.

In the present study, the teachers' approach to teaching changed from a pragmatic to a reflective approach during the studied period. The pragmatic approach has similarities with what Prosser and Trigwell (1999, 2014) define as a teacher-focused approach, where the teacher's intentions are to transmit information to the students. The results shown that a teacher with a focus on information transmission often has students with a surface approach to learning, compared with the students to a teacher with focus on conceptual change and student learning, i.e. a teacher with a reflective approach. Student learning was not the focus of the present study, but we noted that the students'

performance were higher after the second than after the first research lesson (data not shown). If teachers work with CoRe and learning study also stimulate the students' meaning making and approach to learning need to be investigated further.

Professional growth is, according to the model of Clarke and Hollingsworth (2002), a process where reflection and enactment leads to change in one domain, but also to change in other domains. In the present study, teachers have received support in the external domain (time for meetings, lecture and work shop on CoRe) that has led to change in the domain of practice (implement the learning study). In our opinion, this has through reflection led to change in the personal domain, i.e. a change in approach to teaching from a pragmatic to a reflective one. If this change also will result in a change in the domain of consequences (salient outcomes), and in professional growth, i.e. a lasting change, remains to be explored. To conclude, further research is needed on how CoRe and learning study can stimulate teacher's professional development as well as student learning.

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Appendix

Table 3. CoRe template.

Subject area	Big Idea 1	Big Idea 2
What do you intend students to learn about this idea?		
Why it is important for students to know this?		
What else do you know about this idea (that you do not intend students to know yet)?		
What difficulties/limitations are connected with teaching this idea, i.e. what problems may occur in the teaching situation?		
What is your knowledge about students' thinking/misconceptions in the subject and how will these influences your teaching of this idea?		
What other factors influence your teaching of this idea?		
What teaching procedures will you use and what are the particular reasons for using these to engage with this idea?		
In what specific ways will you facilitate students' understanding regarding its ideas?		
What specific ways will you use to find out that the students have learned that you expected them to have done?		