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Primary Student-Teachers' Practical Knowledge of Inquiry-Based Science Teaching and Classroom Communication of Climate Change

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A teacher's practical knowledge contains the teacher's beliefs about the goals, values and principles of education that guide his or her actions in the classroom. There is still a lack of knowledge about how teachers' practical knowledge influences their teaching. The present study examines student teachers' practical knowledge in the context of teaching climate change in elementary schools. Participating student-teachers planned their lessons using the principles and ideas of inquiry-based science teaching and the communicative approach. The same two approaches were applied in analysing the lessons, providing a broader basis on which to study student-teachers' beliefs about teaching science. The analysis revealed different levels of success in terms of implementation of inquiry-based learning; the communicative approach was not comprehensively realised in any class. Stimulated recall interviews highlighted that most student-teachers possessed sufficient knowledge to reflect on their lessons and the necessary awareness to use the communicative approach. By comparing the results of lesson plan analysis, communication analysis and stimulated recall interviews, we can better understand student-teachers' practical knowledge in the classroom.

Keywords: practical knowledge, inquiry, communicative approach, elementary school

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INTRODUCTION

In teacher knowledge research, one important area of study is what teachers know and how their knowing is expressed in their teaching (Connelly, Clandinin, & He, 1997; Simmons et al., 1999; van Driel, Beijaard, & Verloop, 2001; Meijer, Verloop, & Beijaard, 2002; Meijer, Zanting, & Beijaard, 2002; Lotter, Harwood, & Bonner, 2007; Kleickmann et al., 2013). Teachers' practical knowledge has been defined as "the integrated set of knowledge, conceptions, beliefs, and values that teachers develop in the context of the teaching situation" (van Driel, Beijaard, & Verloop, 2001, p. 141). In the case of inquiry-based teaching, teachers' practical knowledge includes, for example, their knowledge about implementation of inquiry-based teaching and their views about its importance (values) and possible benefits for the student learning (beliefs). Teachers' practical knowledge helps their decision-making in developing the ideas that drive their teaching. These decisions are based on their conceptions and beliefs of how to teach specific science content, such as climate change.

Climate change is among the most pressing global challenges currently facing humankind, and as Sharma (2011) has said, science education helps us to live and prosper equitably and sustainably in the era of climate change. Because of its importance there are numerous studies reporting common conceptions of climate change among students or student-teachers (Boyes & Stanisstreet, 1997; Meira, 2006; Johnson, et al., (2008); Jakobsson, Mäkitalo, & Säljö, 2009; Taber, & Taylor, 2009; Boon, 2010; Hansen, 2010; Bell, Matkins, & Gansneder, 2011; Liarakou, Athanasiadis, & Gavrilakis, 2011; Ratinen, 2013; Ratinen, Viiri, & Lehesvuori, 2013; Reinfried & Tempelmann, 2014; Niebert & Gropengießer, 2014). It seems likely that the main problem to understand climate change lies within the distinguishing infrared radiation from ultraviolet radiation, or radiation from thermal energy. Because some primary student-teachers do not understand the nature of the Sun's radiation (Ratinen, 2013), they also fail to understand the role of greenhouse gases in accelerating the greenhouse effect.

Besides the studies concerning student teachers' content knowledge of climate change there are studies about teachers' beliefs of climate change (see more Ratinen, Viiri, & Lehesvuori, 2013). But we still lack understanding of how teachers' personal beliefs about the goals, values, and principles of science education influence their teaching climate change in primary schools. The present study addresses this deficit through four inquiry-based lessons about climate change that were developed by student-teachers for four elementary school classes. The student-teachers' practical knowledge was revealed by how they conceptualised inquiry-based science teaching in their lesson planning and implementation.

Teachers' practical knowledge

Teachers' beliefs about the goals, values and principles of science education are elements of their practical knowledge. Teacher growth is a process of construction of various knowledge types: content knowledge, pedagogical content knowledge and practical knowledge. According to Shulman (1987), content knowledge represents teachers' understanding of the subject matter taught, and pedagogical content knowledge is the knowledge needed to make the subject matter accessible to students. It is known that insufficient content knowledge leads to inappropriate teaching practices (e.g. Gruenewald, 2004). Moreover, in their studies of student-teachers' content knowledge and pedagogical content knowledge, Käpylä, Asunta and Heikkinen (2009) and Kleickmann et al. (2013) have found a close relationship between the two. Unlike those studies, the present research does not address the knowledge needed by a teacher as an advisory script for how to implement a classroom session or lesson plan, and in consequence, no detailed analyses of student-teachers content knowledge and pedagogical content knowledge of climate change are offered here. Instead, this study focuses on the practical knowledge that guides teachers' actions in the classroom, where their beliefs about the goals, values and principles of education play a very important role (Simmons et al., 1999; van Driel, Beijaard, & Verloop, 2001; Meijer, Verloop, & Beijaard, 2002; Meijer, Zanting, & Beijaard, 2002; Lotter, Harwood, & Bonner, 2007). Connelly, Clandinin and He (1997) pointed out that a teacher's practical knowledge resides in the teacher's past experience (their own school history), in the teacher's present mind and body (e.g. based on their level of educational achievement) and in their future plans and actions. In this sense, even novice student teachers without longer teaching experience have some practical knowledge, based on their own history.

For the purposes of this study, two aspects of teachers' practical knowledge are noteworthy: a teacher's beliefs about practice and a teacher's views about effective teaching (Lotter, Harwood, & Bonner, 2007). The present study focuses on teacher's beliefs. According to Hollingsworth (1989) and Pajares (1992), teacher beliefs often include information about students, learning, and instructional strategies. For instance, teachers may believe that they need to transmit knowledge to passive students so that those students will be better prepared for tests. Otherwise, teachers may have particular beliefs about inquiry-based teaching strategies such as a lab work, as the results of this study will subsequently reveal.

Practical knowledge includes elements of formal knowledge within the teaching context. In this study, such elements will be derived from the participating student-teachers' lesson plans for using inquiry-based science education and communication in the classroom. For beginning science teachers, their practical knowledge often consists of elements that are not integrated (van Driel, Beijaard, & Verloop, 2001). This non-integration appears often in novice teachers' teaching, as in differences between their personal beliefs about science teaching and their own actual classroom practice (e.g. Simmons et al., 1999). According to Meijer, Verloop and Beijaard (2002), the relationship between a teacher's practical knowledge and their practice of teaching is unclear. Connelly, Clandinin and He (1997) described a range of methods, such as field notes, interviews, journal writing and autobiographical writing that can be used for studying practical knowledge. However, these methods do not reveal how actual classroom teaching reflects teachers' practical knowledge.

Student-teachers' practical knowledge implementation in real classroom contexts is analysed here by means of the communicative approach (Mortimer & Scott, 2003; Lehesvuori et al., 2011; Ratinen, Viiri, & Lehesvuori, 2013). It is important to know more about student-teachers' practical knowledge because there still is a lack of understanding about how teachers integrate knowledge from different sources, such as inquiry-based teaching and the communicative approach, into the conceptual frameworks that guide their actions in practice.

Inquiry-based learning

The basic principle driving inquiry-based learning is that this approach can more effectively prepare pupils for future challenges and supports a better understanding of science and conducting science in general (Lederman, Antink, & Bartos, 2014).

Pupils participating in inquiry-based teaching achieved better learning outcomes than those in traditional courses (Akkus, Gunelb, & Handc, 2007; Minner, Levy, & Century, 2010). A controversial argument related to inquiry-based learning from Abrahams and Millar (2008) and Hodson (2014) has suggested that doing experiments alone does not lead to better learning outcomes, and that in order to support pupils' learning, teachers must be more aware of the different phases and aspects of inquiry-based learning. Furtak, Seidel, Iverson, and Briggs (2012) pointed out that the pupils who participated in inquiry teaching having teacher-led activities had larger effect sizes than those with student-led conditions. Also there is no single way to do inquiry, but it may entail different levels of openness (Banchi & Bell, 2008):

- *Confirmation inquiry* is useful when a teacher's goal is to reinforce a previously introduced idea; students are provided with a question and procedure for confirming or reinforcing a previously learned idea or practising specific skills of data collection and recording.
- In *structured inquiry*, the question and procedure are posed by the teacher, but students generate an explanation, supported by the evidence they have collected.
- In *guided inquiry*, the teacher provides students with only the research question, and students design the method to test both the question and any resulting explanations.
- At the highest level of openness, *open inquiry*, students have an opportunity to act like scientists: deriving questions, designing and carrying out investigations, and communicating their results.

In summary, inquiry-based science teaching and learning holds that it is important for pupils to consider their own ideas and arguments alongside experimental exercises, and that teachers must be sensitive in collecting pupils' ideas at the appropriate moment and in the other moments guiding students by providing relevant information.

The communicative approach

Although inquiry-based learning can provide a very suitable context for various forms of communications, the danger remains that the approach will not be applied as is intended. Too often, the teacher may be excessively concerned with supplying the right content during inquiry and so fail to incorporate pupils' views into the classroom discourse. To avoid such shortcomings, teachers must be aware of the different aspects of the communicative approach (Mortimer & Scott, 2003), especially the dialogic dimension, which takes pupils' views into account and works with them, free of any evaluative tone.

Mortimer and Scott's (2003) communicative framework accommodates both dialogic and authoritative approaches in the science classroom. Classroom discourse consists of four categories, generated from the combination of two dimensions: interactive/non-interactive and authoritative/dialogic. Within these categories, the communicative approach addresses both the everyday understanding or prior knowledge of learners and the authoritative view of science. The interactive/non-interactive dimension indicates the different ways in which teachers can use talk, whether through whole-class discussions, question/answer sessions or lecturing. Here, the "closing down" phase is potentially very important—for instance, if discussions are "opened up" by a dialogic approach, in which learners are given the opportunity to work with different ideas, discussions should also at some point be "closing down" by advancing an authoritative view.

Communication approach ideas and ideas of inquiry-based teaching are combined in a process model (Table 1) which was introduced to the student-teachers' to use for planning and implementing their learning sequences. They, for example, participated to inquiry-based teaching of combustion and analysed classroom communication in the class where they taught later. This model combines the ideas of both inquiry-based teaching and communication analysis, accommodating all levels of openness of inquiry. The *initiation phase* includes probing pupils' preconceptions, and even though preconceptions might at this point be viewed as misconceptions, pupils should be given the opportunity to express them. Using inquiry-based teaching, the teacher can reveal these (mis)conceptions by employing a dialogic approach and opening up problems to inquiry. At a later stage, the views can be further reflected upon, using the results of the executed inquiry.

The *practising phase* includes planning, executing and reflecting on the results. Hypotheses are made and tested, and results are discussed among peers. The role of the teacher should be more as tutor than director, so laying the ground for meaningful planning and inquiries. Although pupils are expected to do the thinking, the teacher can still raise questions that further guide pupils' work and thinking. It should be emphasised that, in this phase, the teacher should especially encourage pupil-pupil interaction. The *reviewing phase* is essential to achieving educational goals. Although in this phase more authoritative communication is emphasised, preconceptions and misconceptions should be reviewed against scientific results and theories to make explicit the connections between views (e.g. everyday views and the science view) and possible gaps in previous thinking. Since different ideas are still being considered, the dialogic approach remains present, but the authoritative approach should still be implemented when drawing final conclusions, about the content and about the procedure itself. All in all, for meaningful learning of science (Scott & Ametller, 2007), when problems are opened up (dialogic approach) they should also subsequently be closed down (authoritative approach).

Table 1. A process model for planning an inquiry-based learning sequence, showing the learners' action and the classroom communication appropriate to each phase

	Inquiry-based learning [1)]	Communicative approach [2)]
Initiation phase	Learners are engaged by scientifically oriented questions. Learners give priority to evidence.	Opening-up phase: Dialogic and interactive Dialogic and non-interactive
Practising phase	Learners formulate explanations from evidence.	(Emphasis on pupil-pupil interaction)
Reviewing phase	Learners evaluate their explanations in light of alternative explanations. Learners communicate and justify their proposed explanations.	Closing-down phase: Dialogic and non-interactive Authoritative and interactive/non-interactive

Notes. 1) NRC (2000); 2) Mortimer & Scott (2003); Scott & Ametller (2007); Lehesvuori et al. (2011).

This process model was used here to analyse how inquiry-based teaching and the communicative approach was realised in four elementary school classes.

Research question

As described, student-teachers' practical knowledge has remained unclear when autobiographical writing and interview methods are used. This study examines student-teachers' communications in inquiry-based classrooms as a method of revealing their practical knowledge. Stimulated interviews were used to gather student-teachers' self-evaluations of realised classes. The research question is:

- What kind of practical knowledge is revealed by student-teachers' planning and implementation of inquiry and the communicative approach in primary science classrooms?

Detailed analyses of student-teachers' content knowledge and pedagogical content knowledge of climate change play no part in this study, which instead focuses on student-teachers' beliefs about inquiry-based science climate change teaching.

METHODOLOGY

Participants

Participated student-teachers studied in the University of Jyväskylä, in Finland. The university has altogether 15 000 students of which about 2300 in the faculty of education. Data for this study were collected from 20 student-teachers who took part in a course in elementary science pedagogy. Before the present study the student-teachers have accomplished two guided teaching training sessions.

The participants worked in subgroups of five. All twelve three-hour meetings were guided by one university lecturer over a period of four months. Four of those meetings focused on the topic of climate change (see detailed course analysis in Ratinen, Viiri, & Lehesvuori, 2013). Participants were also allowed to ask for help from the lecturer between meetings, either by email or by direct contact. The process model (Table 1) was used as a theory-based planning tool for inquiry-based teaching and learning. Participants analyzed the content taught, examined the teaching material and ascertained pupils' ideas about the topic before teaching. They were provided with different examples of teacher-talk, with directions for classifying classroom interactions within the communicative framework. Following this, each subgroup visited a local elementary school and observed a Grade 6 class. They created teaching strategies and collaboratively wrote a lesson plan for a teaching-learning sequence of four lessons on the topic of climate change. Subsequently, they implemented the lesson plan for Grade 6 students (aged 12 years) in the class they had observed earlier.

Data collection

As Figure 1 indicates, lesson plan content analysis, communication analysis and stimulated recall interviews were used to reveal student-teachers' practical knowledge.

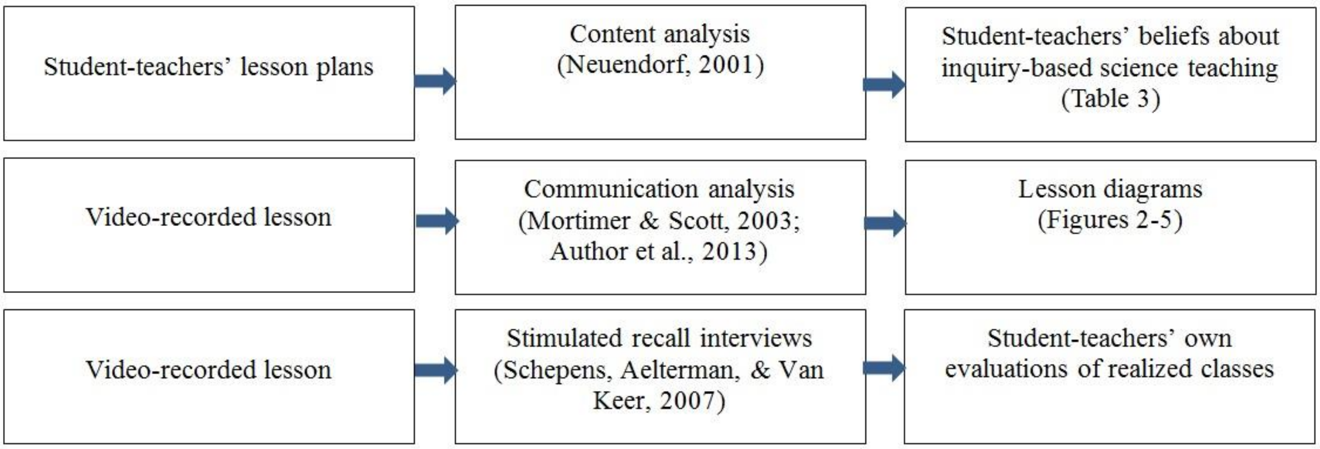

Figure 1. Conceptualization of data analysis

Lesson plan analysis

Lesson plans (n = 4) were checked against the participating student-teachers' ideas of the process model of inquiry-based teaching (Table 1) and their beliefs (Table 2), noting the differences between lesson plans and instruction. Lesson plans generally focus on the pedagogical knowledge and decisions of the teacher (Jacobs, Martin, & Otieno, 2008), and in this study, interpretative content analysis (Neuendorf, 2001) was used to see how the student-teachers' goals, values and principles of teaching (in their lesson plans) embodied their own practical knowledge of elementary science teaching. The purpose was to illuminate their practical knowledge of planning, implementing and evaluating the lesson on climate change, which brings out student-teachers' own thinking and understanding of inquiry-based science teaching.

In order to analyse the lesson plans, categories were developed from combinations of types of practical knowledge. The plans reflected their beliefs about inquiry-based teaching and classroom communication. As a summary, beliefs may form a coherent system for inquiry-based and dialogic teaching or they may be incoherent—for instance, teachers may believe (incoherently) that it is important to teach the facts. As shown in Table 2, the categories included three types of practical knowledge, modified after Meijer, Verloop and Beijaard (2002). *Type I* represents student-teachers who focused mainly on their own teaching strategies and concentrated on the subject matter. *Type II* represents student-teachers whose teaching focused primarily on pupils as individual learners. *Type III* student-teachers' practical knowledge centred on understanding and appropriately using inquiry-based teaching.

Table 2. Description of practical knowledge

Practical knowledge type	Description	Student-teachers' *beliefs* in their lesson plans
Type I	Focus on teaching strategies and content	• The goal was to use dialogic teaching. • Values and principles of inquiry-based teaching were included partly in the lesson plan. • Three-part structure of the model (Table 1) was included incompletely in the lesson plan.
Type II	Focus on individual learners	• The goal was to use collaborative learning. • Values and principles of inquiry-based teaching were included in the lesson plan. • The inquiry itself remained incomplete within the three-part structure of the model.
Type III	Focus on inquiry-based teaching	• The goal was to use diverse communication, and inquiry-based teaching methods were quite well known. • Values and principles of inquiry-based teaching were included in the lesson plan. Three-part structure of the model was well included in the lesson plan.

Notes. Modified from Meijer, Verloop and Beijaad (2002) and Schepens, Aelterman, and Van Keer (2007).

Communication analysis

The video-recorded lessons were systematically coded into the four communicative approach categories developed by Mortimer and Scott (2003) (Appendix 1). The first approach is the *interactive/authoritative* (*I/A)* approach, in which students' responses in the question-answer routine are evaluated, and the teacher avoids diverging ideas. The authoritative approach focuses on the scientific point of view (i.e. the content). Second, and in contrast, the *interactive/dialogic* (*I/D*) approach explores and exploits students' ideas and is not evaluative. Here, the teacher tries to elicit students' points of view and to work with these views (which may contrast with their own). Third, in the *non-interactive/authoritative* (*NI/A)* approach, the teacher presents the scientific content by lecturing, taking no account of contrary points of view. Finally, in the *non-interactive/dialogic* (*NI/D)* approach, the teacher works with contrasting points of view—for example, with common student views—and moves on to a scientific way of explaining phenomena, making the teacher's talk dialogic in nature.

Based on the video analysis, a communication graph was generated. As shown in Figure 2, each of the lessons was mapped, providing a visual representation of the lessons through their patterns of interaction. The communication analysis aims to present, in a readily accessible format, the implementation of the process model (Table 1), including the different teachers' and pupils' interactions and periods of inquiry during the lessons. In the graphs, the practical knowledge types are also marked with symbols I, II and III.

In the present study, the classroom communication analysis began by selecting episodes consisting of teacher-student exchanges, constituting a meso-level analysis of classroom discourse (Tiberghien & Malkoun, 2008; Lehesvuori et al., 2013). The meso-scale approach was selected to create an overview of communications during a 90-minute teaching sequence. Episodes were first selected on the basis of activity type, topic and changes in communication. For example, if the teacher was giving instruction and then shifted to another topic, the episode would be considered to have changed. Changes in communicative approach were considered when making decisions about the episodes; the end of an episode (and the beginning of another) was considered to occur when there were changes in activity, topic or communication. After that, the dominant communicative approach was selected for each episode, enabling scrutiny of whether structures resembling inquiry-based teaching (opening up/inquiry/closing down) could be identified. The communicative approaches adopted by the teacher towards the end of the lesson indicated the closing-down phase, with increased emphasis on the scientific view.

Three researchers independently coded the communications used in the classes and then compared the codings and discussed possible differences to arrive at a common view. Mapping the interaction patterns of the lessons provides an outside observer's overall picture of classroom talk, which can be used for analysis of student-teachers' practical knowledge in real-life teaching situations. While communication analysis revealed researchers' interpretations of the implemented classes, the stimulated interviews clarified in greater depth student-teachers' own thinking about inquiry-based teaching and classroom communication. This triangulation method also improved the study's validity. According to Meijer, Verloop and Beijaard (2002), multi-method triangulation is a worthwhile procedure for enhancement of the internal validity of qualitative studies, especially on a complex topic such as teachers' practical knowledge. The level of openness in inquiry was analysed by reference to Banchi and Bell's (2008) categories presented earlier.

For classroom video recording, pupils' parents signed consent forms, which is an essential part of ethical practice in science education research. Consent forms allow respondents to decide which parts of their data can be used for the purposes of the study, and whether they require anonymity and removal of the pupil's facial image.

Stimulated recall interviews

Stimulated recall group interviews (e.g. Schepens, Aelterman, & Van Keer, 2007), (n = 4) were used to gather student-teachers' own evaluations of their written lesson plans and of their implementation of the inquiry-based lesson. Video clips of various communicative approach episodes during the implemented lessons was played back to stimulate retrieval of any thoughts the participants had during their own lesson plans and teaching.

RESULTS

In this section is presented how lesson plan content analysis, communication analysis and stimulated recall interviews were used to reveal student-teachers' practical knowledge.

Lesson analysis of class A: Polar bear

The topic of this lesson was the melting of polar ice and its influence on the lives of polar bears in the Arctic region. The student-teachers planned nine episodes, of which four were dialogical. Lesson plans revealed their intention the student-teachers' planned to consider pupils' everyday views at the beginning of the class, as well as pupils' pre-knowledge of science in various contexts during the lesson. The lesson was planned to end with conversation about the hypothesis of the experiment: dirty ice melts faster than clean ice (the black carbon as an absorbing component). They planned five authoritative episodes, including storytelling about the polar bear and the setting up of the lab work. The topics for the three planned group sessions were principles of climate change, consequences of climate change and prevention of climate change.

The communicative approaches and active inquiry phases of the lesson as realised are graphically presented in Figure 2, which again uses the symbols I, II and III to mark the practical knowledge types used in the lesson plan, along with short bubble descriptions of the three types. The figure shows explicitly the degree of coherence between beliefs (plan) and enacted practice; differences or compatibility between lesson plan and realised teaching are described in the text boxes.

In Figure 2, the initial opening-up phase (about 0–5 min) is realised by means of the different communication approaches used by the teacher. This leads into periods of inquiry-based activities, punctuated by further guidelines given by the teacher—in this instance, through the reading of a story—so that the pupils were engaged by scientifically-oriented questions.

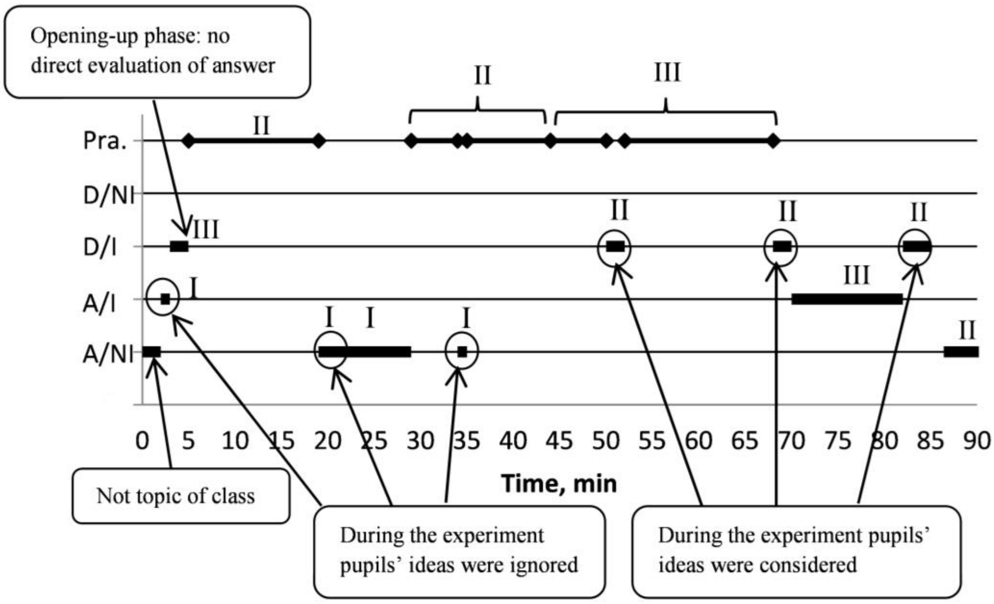

Figure 2. Lesson diagram of Class A. (A/NI = Authoritative and non-interactive, A/I = Authoritative and interactive, D/I = Dialogic and interactive, D/NI = Dialogic and non-interactive, Pra. = Practising phase; I = Focus on own teaching and concentration on subject matter. II = Focus on pupils as individual learners. III = Basic understanding of inquiry-based science in lesson plan and its implementation).

Here, the student-teacher asked pupils about the melting of clean and dirty ice. He collected pupils' ideas without directly evaluating the answers; in this way, pupils' prior ideas could be taken into account before their group work began. After brief instructions, pupils commenced work in three groups. Each group carried out three tasks, with the purpose of formulating explanations based on the evidence provided by the student-teacher. The first inquiry-based task (minutes 5–19) followed the confirmation inquiry, where the student-teacher's goal was to reinforce a previous introduced idea. Pupils' ideas about the greenhouse effect were gathered through small-group work, guided by the student-teacher. Between the first and second task, a story about a polar bear was told by the student-teacher (minutes 23–29). The second task (minutes 29–44) was a structured inquiry related to the story about a polar bear and the melting of a northern polar glacier, in which the pupils generated an explanation, supported by the evidence they had collected from the experiment and the story. The third task (minutes 44–68) included planning an advertisement to encourage the reduction of climate change. This included sources for guided inquiry, and pupils designed and conducted a procedure before presenting their findings and results as a poster.

The melting of two different types of ice was measured at approximately 15-minute intervals. While the teacher carried out the actual measurements, the whole class was encouraged to make observations. Once the final measurements were conducted, observations were made on the amount of melted ice. During this phase, an interactive/dialogic communicative approach was used, although authoritative passages gently directed the discussion toward conclusions. Pupils enacted a play (minutes 70–82), in which each pupil was assigned a character (e.g. polar bear, atmosphere, sun ray etc.). Each time this character was mentioned in the play, the pupil(s) had to demonstrate the actions of this character. Pupils' preconceptions were then addressed within the final conclusions (minutes 82–90).Throughout the teaching sequence, communicative approaches can be clearly identified that signal the purposeful use of various discursive strategies. During the dialogic episodes, pupils' contributions were noted in a supportive or neutral tone, fostering an open climate that invited further contributions from pupils. With the student-teacher acting as co-inquirer, group work aimed to embrace collective and reciprocal approaches to pupil inquiry.

Student-teachers did not dialogically open up the lesson, so ignoring pupils' pre-knowledge. During the inquiry session, planned interactive dialogic sessions were realised as authoritative and interactive. Dialogic and interactive teaching was clearly realised during the applied task towards the end of the class and during the task in which pupils examined dirty and clean ice. Overall, student-teachers' practical knowledge was relatively good in this class because they used the three-part pattern of the model (Table 1). However, the review of the lesson did not take account of pupils' pre-knowledge, and so knowledge was not constructed by dialogic interactive communication. Clearly, there was a conflict between the interactive/dialogic approach and finding the right answers with a teacher's support.

Lesson analysis of class B: The greenhouse effect

The topic for Class B was the greenhouse effect and CO_2 as a greenhouse gas, planned as five dialogic and two authoritative episodes. Lesson plans noted that dialogic conversation in the class would consist of engagement with the topic, discussion of how people can affect climate change and discussion about the results of the experiment on the greenhouse effect. The planned authoritative episodes included a "lecture" about the greenhouse effect as a natural process and the experimental setup. The group tasks consisted of a poster-making session and a gallery presenting the posters, ending the class dialogically.

This class began with the student-teacher's introduction of the class topic (0–1 min). Subsequently, the class consisted of sessions led by the student-teachers (1–6 min), (6–8 min), (8–22 min), (22–29 min); the experiment on the greenhouse effect, in which water vapour and CO_2 were heated up (29–32 min and 57–59 min); guidance for group work on the greenhouse effect (32–38 min) and group work implementation (38–57 min); and, finally, review of the group work (59–71 min). At the end of the class, student-teachers reviewed the class as a whole and gave feedback on students' participation in the class (72–75 min).

To some extent, the teaching sequence here mirrors the model of inquiry-based learning (Figure 3). However, the dialogic opening-up phase is closed before the experiment, as seen in the dominating authoritative episodes (7–38 min). The practising phase itself was carefully planned and followed a confirmation inquiry in which pupils conducted investigations and practised a specific inquiry skill, such as collecting and recording data. The practising phase represented coherent practical knowledge, and pupils had the freedom to peer-evaluate the results before a student-teacher reviewed the essentials. During this phase, an even more authoritative and goal-directed approach would have been appropriate for the closing phase of the inquiry.

As Figure 3 shows, authoritative communication dominated Class B. Lesson plans showed that the student-teachers' purpose was to apply the interactive dialogue approach in considering pupils' everyday views of climate change at the beginning of the class. However, the opening-up phase was not implemented and so pupils did not express their own ideas, nor did student-teachers review pupils' ideas with reference to the scientific point of view (principle of the greenhouse effect: emitted IR-radiation is absorbed by the greenhouse gases and heat is re-radiated in all directions). This teaching reflects incoherent practical knowledge of inquiry-based and communicative science classes.

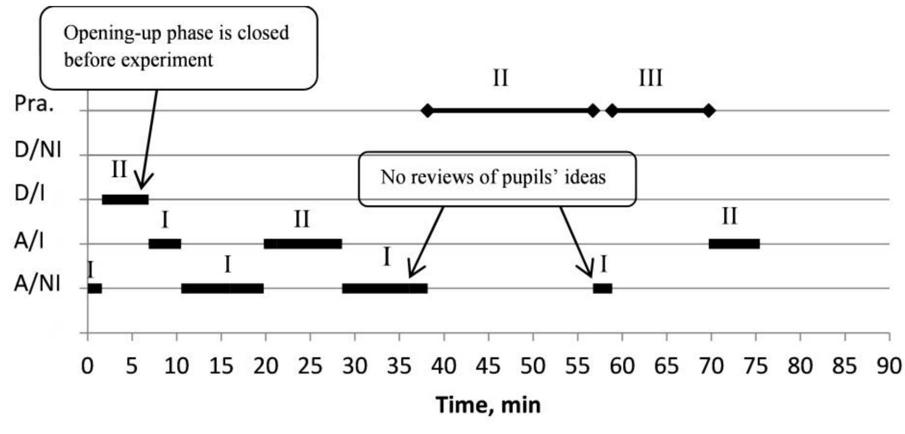

Figure 3. Lesson diagram of Class B. (A/NI = Authoritative and non-interactive, A/I = Authoritative and interactive, D/I = Dialogic and interactive, D/NI = Dialogic and non-interactive, Pra. = Practising phase; I = Focus on own teaching and concentration on subject matter. II = Focus on pupils as individual learners. III = Basic understanding of inquiry-based science in lesson plan and its implementation).

Lesson analysis of class C: The life cycle of porridge

In this class, student-teachers had difficulties with the communicative approach in lesson planning. They planned seven episodes, but only two were dialogic or interactive; two were authoritative, and the rest of the episodes were not determinate as any of the communication types. The dialogic and interactive episodes consisted of conversation about the consequences of climate change and the life cycle of porridge and its environmental impacts. In this lesson energy consumption of porridge cooking was measured and further discussed it's influence to the life cycle of porridge. Authoritative episodes included teacher's talk about the principles of the greenhouse effect and climate change. The principle of life cycle analysis was planned as group work in which pupils would discuss the phases of the life cycle of porridge. The plan was to end by summarising the main topics of the class with the pupils' involvement.

To begin Class C (Figure 4), the teacher contrived some practical issues and collected pupils' preconceptions about climate change (0–5 min). The class consisted of student-teacher-led sessions with the children (5–7 min, 7–15 min, 15–23 min, 23–26 min, 32–36 min and 66–75 min); completion of a worksheet (26–32 min); and the initiation and implementation of an experiment, cooking porridge in a saucepan with and without a cover (36–38 min, 41–56 min, 56–66 min).

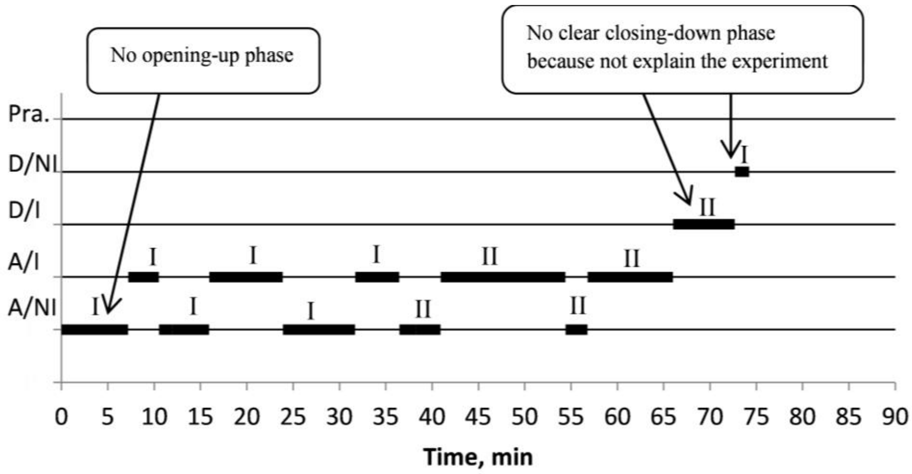

Figure 4. Lesson diagram of Class C. (A/NI = Authoritative and non-interactive, A/I = Authoritative and interactive, D/I = Dialogic and interactive, D/NI = Dialogic and non-interactive, Pra. = Practising phase; I = Focus on own teaching and concentration on subject matter. II = Focus on pupils as individual learners. III = Basic understanding of inquiry-based science in lesson plan and its implementation).

This teaching sequence involving the life cycle of porridge did not appropriately follow the inquiry-based learning approach (Figure 4). Unfortunately, the lesson failed to employ the full range of communicative options and, as can be seen from the communication graphic, practising phases were completely absent from this lesson. Whereas Class A effectively illustrated the three-part pattern of the model, Class C had no opening-up, maintaining authoritative communication throughout the lesson and omitting any authentic phases of inquiry or dialogue. Closing-down was student-teacher guided classroom communication which was unrelated to the experiment of cooking porridge. In short, this class represents student-teachers' incoherent practical knowledge of inquiry-based science teaching and failed to follow any of the types of inquiry identified by Banchi and Bell (2008). In particular, porridge cooking as an example experiment failed because, among other things, student-teachers neglected to measure electricity consumption after cooking.

Despite their plans to use dialogic communication for gathering pupils' ideas, the student-teachers' lesson included neither opening-up nor closing-down. The class as implemented maintained the authoritative view of science throughout the lesson, omitting any authentic phases of inquiry or dialogue. Because the concept of the life cycle of porridge was challenging for the student-teachers, they talked authoritatively. While pupils' lack of participation in the discussion also reflected their insufficient pre-knowledge, student-teachers' dialogic talk (as they planned it) could have prompted more active conversation.

Lesson analysis of class D: Climate change and temperature zones

Class D involved temperature zones and the relationship between planetary phenomena and climate change. Student-teachers planned eight teaching episodes; of these, two were planned to be non-interactive and authoritative, and the remaining episodes were intended to be interactive and dialogic. Lesson plans noted that the intention was to use pupils' everyday views in dialogic conversation at the beginning of the class. A teacher-centered episode of the principles of temperature zone was also planned as dialogic. Pupil-centered group work on the influence of climate change for temperature zones was also planned as dialogic and interactive. Student-teachers planned to end the class with a dialogic conversation about "What you have learned about climate change".

At the beginning of the class (Figure 5), student-teachers introduced the topic and themselves (0–3 min). The class continued with sessions controlled by the teacher (3–17 min, 17–29 min, 29–33 min, 70–72 min and 72–81 min); teacher's instructions for group work on climate change influences and changing temperature zones (33–43 min); group work implementation (43–60 min); and students' presentation of the group work to the other pupils (60–70 min).

In this class, the teaching sequence partially followed the process model of inquiry-based learning, indicating that student teachers' practical knowledge was good enough. Pupils' preconceptions were mapped and foregrounded before executing inquiries (Figure 5); however, in the class, pupils did not advance their own thinking because the student-teachers did not open up the class by asking scientifically relevant questions. Although the student-teachers' purpose was to dialogically review the class, pupils' alternate perspectives were ignored when the student-teacher compared and linked pupils' concepts to the scientific point of view. The student-teachers' planned dialogic interactive sessions were realised most clearly during the inquiry session on planetary phenomena which was a mental model for illustrating the greenhouse effect. The class did include confirmation inquiry because pupils confirmed a previously learned idea in their group work. In addition, the essential concepts were reviewed at the end. Despite the dialogic aspect of the reviewing episodes, however, the student-teachers were concerned with scientific correctness at this point. As the diagram reveals, authoritative episodes followed the dialogic ones before the actual inquiry, and so the dialogic model was not fully implemented, reflecting relatively incoherent practical knowledge. Although the student-teachers' purpose was to dialogically review the class, pupils' perspectives were ignored.

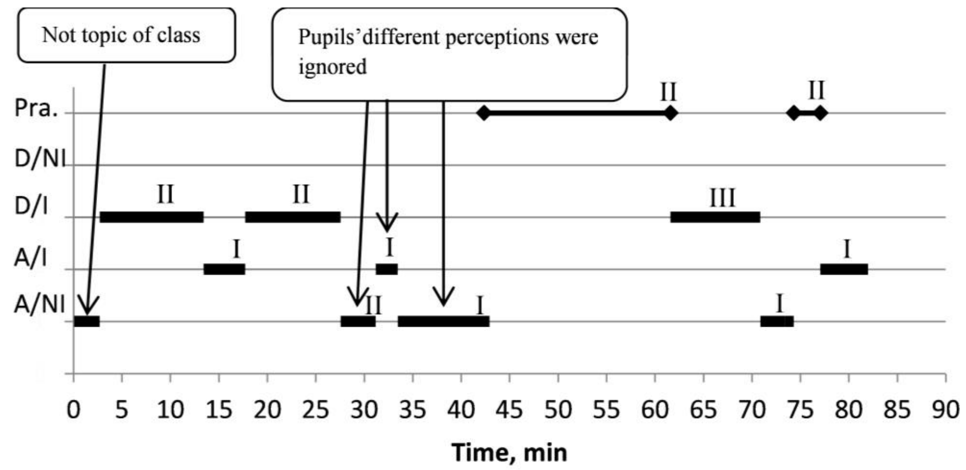

Figure 5. Lesson diagram of Class D. (A/NI = Authoritative and non-interactive, A/I = Authoritative and interactive, D/I = Dialogic and interactive, D/NI = Dialogic and non-interactive, Pra. = Practising phase; I = Focus on own teaching and concentration on subject matter. II = Focus on pupils as individual learners. III = Basic understanding of inquiry-based science in lesson plan and its implementation).

The detailed analysis of student-teachers' lesson plans reveals a mixture of different practical knowledge types (Table 2). Table 3 shows the results of the analysis, in which, for instance, number 4 in the Class A Type I cell indicates that student-teachers fourthly had an idea in their lesson plan that was categorised as Type I practical knowledge. These four realisations of type I practical knowledge are also marked in Figures.

Table 3. Student-teachers' beliefs (i.e. their practical knowledge of inquiry-based science teaching) revealed from their lesson plans and lesson realization

Class	Student-teacher's practical knowledge due to communication analysis		
	I	II	III
Class A; Polar bear	4	6	3
Class B; The greenhouse effect	5	4	1
Class C; The life cycle of porridge	7	5	0
Class D; Climate change and temperature zones	5	5	1
Sum of types	21	20	5

Notes. Each cell gives the number of instances the student teachers' lesson plan evidencing use of a certain type of practical knowledge (see Table 2). (I = Focus on own teaching and concentration on subject matter. II = Focus on pupils as individual learners. III = Basic understanding of inquiry-based science in lesson plan and its implementation).

As a summary of the results of communication analysis the main differences between lesson plans and lesson implementations were:

- Class A: Student-teachers did not dialogically open up the lesson, thereby ignoring pupils' pre-knowledge (See Figure 2).
- Class B: The opening-up phase was closed before experiment. Student-teachers did not review pupils' ideas according to the scientific point of view. (See Figure 3)

- Class C: No opening-up; no dialogic closing-down; student-teachers did not explain the experiments. (See Figure 4)
- Class D: Pupils did not advance their own thinking, and their perspectives were ignored when the student-teacher compared and linked pupils' concepts to the scientific point of view. (See Figure 5)

And when compared with the practical knowledge types of Table 2 the main differences revealed by communication analysis were:

- Type I: Dialogic teaching was realized as authoritative, values and principles of inquiry-based teaching were ignored in the lesson. Three-part structure of the model was incomplete.
- Type II: Pupils did not mutually share their ideas, values and principles of inquiry-based teaching remained deficient in the experiment, the inquiry itself remained incomplete within the three-part structure of the model.
- Type III: Dialogic and inquiry-based teaching was realised quite well, values and principles of inquiry-based teaching realised in the class and lesson were critically reflected, three-part structure of the model was realised quite well in the class.

Stimulated recall interviews

Stimulated recall interviews revealed student-teachers' incoherent practical knowledge and the fact that they failed to comprehensively implement the communicative approach in their science classroom, and so the ideas of the lesson plans were not realised in their teaching. Student-teachers initially proposed to use interactive dialogic talk, but in the stimulated recall interviews, many student-teachers admitted to having used closed questions, which lead learners to give direct, concise answers. It follows that real dialogue did not occur, especially at the beginning of lessons. Stimulated recall interviews revealed that student-teachers in Class C had not internalised the principles of the communicative approach and inquiry-based science teaching.

During the stimulated recall interviews, student-teachers critically evaluated their teaching, reflecting their practical knowledge. Even where their beliefs about teaching included dialogic aspects, they ignored these in their teaching as they evaluated the implementation of the communicative approach in their science classrooms.

> Student-teacher b (Class A): Not just a teacher lecturing ... but I bet that we sought some answers. We might not underpin the pupils' answers, nor begin to lead the instruction on that basis. We had specific questions, and the discussion was not entirely of dialogue, because we did not rely on the children's thinking. We expected the children to give certain answers, and we confirmed it when we got the right answer. I did not know that, how it could have to do with it.

Student-teachers understood the difficulties in asking relevant, open-ended and encouraging questions. When asked how pupils discussed among themselves in their small groups, student-teachers' responses included the following.

> Student-teacher a (Class A): I basically steered the discussion and helped pupils to think, and the pupils did not, actually, ask spontaneously (scientific questions).
>
> Student-teacher d (Class C): In the beginning of the class, I worked hard to motivate pupils to participate in the discussion.
>
> Student-teacher a (Class C): I could have given time to the pupils to answer, and not immediately give a new question… we followed IRE discussion type (Student c).

> Student-teacher c (Class D): Pupils' activities varied according to different subjects and different tasks.
> Student- teacher c (Class B): If we would have known pupils and their discussion culture better… it would have been easier to communicate with them.
> Student- teacher b (Class A): I do not know about … or how to make the learning situation more familiar.

It seems clear that the student-teachers in all classes had Type II practical knowledge (Table 4) in that they focused primarily on pupils rather than on their ability to act as a Type III expert in a science classroom. Specifically, student-teachers viewed pupils as individual learners during group work. When the topic of the lesson was scientifically challenging, the authoritative talk type was more predominant in student-teachers' lessons, indicating that the content level of the class significantly influences communication in the science classroom. According to student-teachers, their lesson plans were carefully designed, and the teaching implementation did not manifest major subject-matter mistakes. However, stimulated recall interviews revealed student-teachers' worries (especially in class C) about the insufficiency of their understanding for use of inquiry in climate change teaching.

The stimulated recall interviews highlighted student-teachers' challenges in starting discussions with pupils and creating real interactions among groups, with other groups and with the teacher. However, student-teachers indicated in the interviews that pupils' ability to participate in the discussions varied significantly, according to the type of task. Overall, the stimulated recall interviews revealed the integrated set of knowledge, conceptions, beliefs, and values that student-teachers developed in the context of teaching about climate change.

DISCUSSION

FINDINGS

Our aim was to find what kind of practical knowledge is revealed by student-teachers' planning and implementation of inquiry and the communicative approach in primary science classrooms. Teachers practical knowledge has been studied in many studies (e.g. Connelly, Clandinin, & He, 1997; Simmons et al., 1999; van Driel, Beijaard, & Verloop, 2001; Meijer, Verloop, & Beijaard, 2002; Meijer, Zanting, & Beijaard, 2002; Lotter, Harwood, & Bonner, 2007) but the present study brings a new perspective to the methodological discussion for studying teachers' practical knowledge. As Meijer, Verloop and Beijaard (2002) pointed out teachers' practical knowledge is viewed as a multi-dimensional concept, requiring multiple instruments for its exploration. We aimed to reveal the multi-dimensionality by comparing the results of lesson plan analysis, communication analysis and stimulated recall interviews. The lesson plan analysis gave a picture that their beliefs seem to be relatively coherent in relation to the elements of inquiry-based teaching as presented in Table 1. They planned to use relevant inquiry-based "learn by doing" experiments (Johnston et al. (2008) such as melting ice and also model-based experimental demonstration for illustrating the greenhouse effect (Reinfried, & Tempelmann, 2014). The results is not very congruent with Käpylä, Asunta, and Heikkinen (2009) who discovered that primary student-teachers' had problems in choosing the most important content in their lesson plans.

According to van Driel, Beijaard, and Verloop (2001), teachers develop their practical knowledge in the context of the teaching situation. The communication analysis reveals explicitly the kind of practical knowledge student-teachers really used in the classroom. These findings are in contradiction to the picture given by the lesson plan analysis. Student-teachers' teaching was not in line with their lesson plans (see Table 3). The experiments they used remained vague, because interaction with pupils did not foster pupils' thinking. Student-teachers (other than class C) planned to teach the principles of climate change dialogically, but they ignored pupils' pre-knowledge. Additionally, the "closing-down" component (see Ratinen, Viiri, & Lehesvuori, 2013) of the classes reveals the incoherence of student-teachers' practical knowledge, as they did not clearly close down the lesson or review the main points of the climate change class. For example, the results of measurement of electricity consumption was ignored in relation to the amount of greenhouse gases. Moreover, the stimulated recall interview reinforced the impression that student-teachers' purpose was to use both inquiry-based teaching methods and experiments as well as considering pupils' own ideas and arguments. This result aligns with Childs and McNicholl (2007) where the student-teachers mentioned primary science teaching requiring teaching without formulas, with a stronger focus on phenomena and the science teaching explanations. Othervise, the result is similar with the finding of Meijer, Zanting and Beijaard (2002) that student-teachers' recall in interviews looked beyond the "how" and into the "why" of teaching.

As the lesson diagrams illustrate, the analysis reveals different levels of success in terms of implementation of inquiry-based learning, and that student-teachers' practical knowledge remained relatively incoherent. Their practical knowledge also varied significantly, with extremes represented by the teachers of Classes A and C. The student-teachers of Class A demonstrated their above-average ability to plan, implement and critically evaluate an inquiry-based science lesson. In contrast, student-teachers in Class C did not refer to the provided model at all. Student-teachers' readiness to apply dialogic communication in their teaching also varied significantly. Those classified as Type III (i.e. having a basic understanding of inquiry-based science in lesson planning and its implementation in actual classroom communications) performed relatively poorly in all four classes. This means that student-teachers knew the appropriate teaching strategies even for dialogic teaching, but they did not know how these should be enacted in the classroom.

Implications

The interactional graphics (Figures 2, 3, 4 and 5) could be applied in teacher education while student-teachers observe classroom practice (Viiri, & Saari, 2006). Following the observations, in which individual notes are made in an assigned form, student groups could negotiate a communication graphic of the observed lesson, encouraging them to truly engage with the different interactional options and what they mean for their practical knowledge. This would hopefully support student-teachers in lesson planning and in the realisation of inquiry-based teaching.

One interesting option for further research would be to use the lesson diagrams with student-teachers as well as in-service teacher education to develop practical knowledge in science classrooms. As indicated by their lack of coherent practical knowledge here, student-teachers may well need more concrete practice in implementing a dialogic approach.

Aside from the questions of time and discipline (Scott, Mortimer, & Aguiar, 2006), the dominant school culture may not be open to dialogic innovations. These challenges arguably also apply to the professional development (PD) of in-service teachers. The present study also suggest that, to be successful, a PD course must not only include inquiry-related knowledge but must also assess and address teachers' core teaching conceptions of the goals, values and principles of education (Lotter, Harwood, & Bonner, 2007). To challenge this prevailing culture, dialogic issues and teachers' practical knowledge must be emphasised in both initial and in-service teacher education. However, student-teachers are not often able to make effective or appropriate use of pedagogical strategies as discussed in PD courses because their practical knowledge is compared at novice level (Meijer, Zanting, & Beijaard, 2002). Indeed, student-teachers' perceptions and methods of teaching are based strongly on their own school experiences as pupils (Abell, 2007), and if PD fails to explicitly address different approaches to teaching, there is a danger that those beliefs will persist throughout teacher education and teaching service (Fajet, Bello, Leftwich, Mesler, & Shaver, 2005). On this basis, increasing teacher awareness at both pre-service and in-service levels will be essential in initiating any reform of practice (Kagan, 1992).

CONCLUSION

Our findings show that student teachers' practical knowledge is not coherent and different methods to reveal it may give different and even contrary pictures. Future studies should use besides the methods applied in previous studies (e.g. field notes, interviews, journal writing) also methods more related to actual classroom teaching. Those could include the graphical analysis based on lessons videos.

Limitations

The results of the present study have potential as a guideline for the development of teaching. Since the results are from some lessons they should not be generalized and they should only be taken as examples. Further research is required to get more information about the learning processes related to practical knowledge.

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APPENDIX

Description of communication analysis

Communicative approach	Description	Example	Comment
Interactive authoritative approach I/A	The teacher's aim is to arrive at the idea of some specific and scientific point of view	*Teacher: Just think about melting glaciers. When glaciers melt, then something else also happens in the ocean. When you look at this picture, what do you think has happened in the ocean? When you look at that strip of land and its surroundings?* *Student: It has been contaminated.* *Teacher: Yes, it's quite dark. But what else has happened? Think about the fact that there is water in this picture and there is also a kind of border here?* *Student: The water level has risen.* *Teacher: Yes, yeah, that is what happened. That's right: the city is now located under the sea.*	This excerpt is an example of a typical student-teacher's authoritative communication (lines 1 and 3). In the third line, the teacher ignores the pupil's thinking and restrains the direction of the communication by guiding the pupil towards the answer that is in her mind.
Interactive dialogic approach I/D	The teacher listens to and considers students' points of view, and tries to elicit students' views	*Teacher: What do you think: does dirty or clean ice melt faster?* *Student 1: Dirty.* *Teacher: Why do you think that dirty ice will melt faster?* *Student 1: I don't know. It's somehow warmer. I think. It gets warmer faster.* *Teacher: Okay. (Gives the floor to the next student)* *Student 2: It's clean.* *Teacher: Hmm. So why do you think that clean ice will melt faster?* *Student 2: It's clean, so probably its molecules will melt easier.*	This excerpt shows how the student-teacher explores students' understanding by asking them to clarify and focus their ideas (lines 3 and 7). The student-teacher does not evaluate the correctness of the students' answers but makes it possible for the students to share their ideas.
Non-interactive authoritative approach NI/A	The teacher explores a specific and scientific point of view.	*Teacher: Jape felt sad and asked the bird, "Why is this all happening?" Jape had been having a strange day. The bird answered, "My cousin, far away in Australia, told me yesterday that there have been floods in their nesting area, and their own nest was flushed away. And the new risk for my cousin will be hurricanes." The bird sighed. She knew the reason for the changing situation, but she did not want to tell the cause to small Jape.*	This example shows how the teacher read a story about a polar bear called Jape. There is only the scientific point of view in this story.

Non-interactive dialogic approach NI/D	The teacher explores various points of view, setting out, exploring and working on the different perspectives	*Teacher: You have many opinions and responses for the meaning of climate change. And all of your responses indicated that climate, somehow, changes. And you are right. So, climate change means, literally, a change in climate and a change in the Earth, somehow. So, it has been observed that the average temperature has, over the years, risen across the Earth.*	This excerpt was taken from the lifecycle class. The student-teacher reviews pupils' pre-knowledge and associates those ideas with climate change.

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