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465

Sami Lehesvuori

Towards Dialogic Teaching in Science

Challenging Classroom Realities through Teacher Education

JYVÄSKYLÄN YLIOPISTO

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ABSTRACT

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Finnish summary

The aim of this study was to explore dialogic teaching in school classroom and teacher education contexts. Despite moves towards more socially-oriented and student-centred curricula, science classroom communication remains prevailingly authoritative and monologic. In order to address the dialogic gap existing in the field, within this study an intervention was developed and executed to increase student teachers' awareness of the dialogic aspect and its role in science classroom communication. Drawing on previous scholarly work in the field of dialogic teaching and teacher education, an interventional teaching programme focusing on teacher talk was designed. The programme covered the planning, execution, reflection and analysis of science lessons orchestrated by student teachers themselves. Thus, in addition to introducing the background theory of dialogic teaching, the empirical aspect was also given cogent weight. Participants of the study within the teacher education context included both science student teachers and primary school student teachers. The second part of the study assessed how dialogic teaching manifests in the science classroom without pre-intervention. Participants in this part of the study included volunteer science teachers and their classes.

The most essential theoretical contribution of this study is to further understanding of time as an intentionally manageable dimension when using different types of communication in science classrooms. The theoretical framework proposed by this study explicates how different types of communication and activities can link together and foster continuity, and specifically cumulativity, within meaningful communication. Whilst this study recognises the current foregrounding of dialogicality in educational research, it is considered that science classroom communication should include both authoritative and dialogic aspects. The main results of this study reveal that although student teachers are able to go beyond authoritative modes of teaching and communication, there are still major challenges along the way towards sustainable dialogic reformation. The major challenge is to unhinge the prevailing school culture, which remains reliant on outdated forms of teaching. More specifically, the dominant authoritativeness observed in the classroom should be challenged, which is possible only by preparing teachers with more versatile communication skills.

Keywords: classroom communication, dialogic teaching, meaningful learning, communicative approach

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LIST OF PUBLICATIONS

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1 INTRODUCTION

The aim of this study was to explore science classroom communication facilitated by both student teachers and in-service teachers. In addition, student teacher views on classroom communication in science were examined. The research was conducted within a sociocultural framework stressing communication as a mediator of development of both communities and individuals. The sociocultural perspective on teaching and learning underscores the importance of learning within a social context and the potentiality of talk to enable the co-construction of knowledge (Vygotsky 1978). Language use is seen as having a profound effect on the development of thinking and is an area of growing interest within educational research (e.g., Edwards & Mercer 1987; Lemke 1990; Mercer 1995; Mercer 2000; Mortimer & Scott 2003; Wells 1999). The emphasis on developing reasoning and communication skills answers the challenges of the future society: in the modern world the problem is not how to get information, but rather how learners can be better prepared as critical consumers of knowledge and creative thinkers (Carneiro 2007). Another future concern is loss of interest in science, which has been linked to traditional, monologic and transmissive modes of teaching (Lyons 2006). In the Finnish context of this study, although Finland has ranked top in international PISA (Programme for International Student Assessment) comparisons, Finnish students are worryingly uninterested in learning science (OECD 2007, p. 141). These concerns call for specific interventions for teacher education drawing on previous perspectives on teaching and learning in order to prepare prospective teachers with more versatile communication skills.

Given the increasing importance of more social and student-centred approaches in recent learning theories, this study illustrates an innovative teaching programme that aims to enrich student teachers' views about the use of communicational approaches in the science classroom. The study also highlights the need for specific attention to be given to the ways in which teacher talk is addressed during initial teacher education (Crespo 2002).

Briefly, the aim of this study is to seek to enrich teacher education by introducing student teachers to the *dialogic* aspect of classroom communication in order to destabilise the putatively ingrained authoritative nature of science teaching. Before introducing the study in detail, light is shed on science classroom realities in order to foreground the context of the study and the need for more dialogic pedagogy. The notion that the dialogic aspect of communication and dialogue play a central role in achieving a more meaningful and deeper level of learning has been broadly gaining ground (Alexander 2006; Lyle 2008; Mortimer & Scott 2003; Skidmore 2006). The term "dialogic" briefly refers to mutual appreciation of different ideas (Bakhtin 1986), while the necessity of the social aspect of instructional communication derives from the sociocultural perspective.

As regards the descriptions of dialogic interaction given within this study, dialogic interaction necessarily involves the teacher communicating verbally with students, or students interacting with other students. Interaction without the dialogic aspect can be purely physical, without verbal communication. More generally, dialogic interaction is related to communicative dialogue, emphasising the intended and cooperative nature of interaction, and is initiated through the implementation of dialogic approaches to teaching. Furthermore, whenever the term communication is stressed within this study, the monologues of the teacher are equally considered as an instructional approach to teaching scientific content. Moreover, as discussed later in more detail, although the dialogic aspect is highlighted, it is considered to be just one part of the overall communication constituting meaningful learning of science.

This doctoral dissertation is based on four articles. The individual articles focus on specific subjects and subtopics reviewed in the main body of the dissertation. The dissertation draws together the separate studies and critically considers the broader implications of the research findings, for example with regard to the professional development of teachers. By doing so, a broader picture of teacher education and teacher preparation programmes is taken into account with respect to the implications for teacher education. This dissertation is recommendable reading for all those interested in classroom communication and its various aspects, such as dialogic teaching emphasising the social, interactive and reciprocal aspects of teaching and learning. Although this dissertation focuses on science teaching, the topics discussed are of relevance to educational researchers, teachers and educators of all disciplines.

The following sections provide a brief overview of the contextual and theoretical background of this study. Before introducing the specifics of dialogic pedagogy and theory, an overview of the sociocultural perspective is provided beginning with an overview of current trends in science classrooms and foregrounding the need for different aspects of communication.

1.1 Current trends in science classroom communication

For over a decade there has been a push towards more *inquiry-based approaches* to science teaching (NRC 1996), with inquiry-based methods argued as being one of the best approaches to teaching science (Akerson 2007; Akkus, Gunel & Hand 2007). The features of inquiry are also present in the Finnish core curriculum (FNBE 2005). In general terms, inquiry-based teaching and learning is usually initiated via a problem-based approach where the teacher poses a question for students to solve rather than posing a statement. Learners are expected to seek and shape information usually in groups, supported by teacher guidance. Besides the focus on scientific content, inquiry stresses the process of doing science, such as making observations and critical argumentation.

Furthermore, it has been stated that specific kinds of argumentation could support the development of critical reasoning skills in students (Frijters, ten Dam & Rijlaarsdam 2008). In Finland, however, inquiry approaches do not seem to correlate with better learning outcomes (OECD 2007). In the reality of the classroom, experiments are worryingly too often carried out following predefined, narrow steps rather than providing an environment for authentic inquiry. This kind of learning is referred to as simple rather than complex inquiry and does not capture the true nature of scientific inquiry (Akerson 2007; Dolan & Grady 2010; Saari & Sormunen 2007). Furthermore, in drawing on traditional notions of the importance of language, inquiry guidelines seem to neglect the social dimension of learning, or at least it is not sufficiently highlighted or described (Oliveira 2009, 2010a).

Science classrooms are typically characterised by specific communication traits. Phenomena are often described, modelled and explained in disciplined and firmly ingrained ways, thus seeming to narrow down opportunities for authentic interpretation (Scott, Ametller, Mortimer & Emberton 2010). Traditional transmission modes of teaching have been criticised for limiting students' opportunities to share their everyday views (e.g., Lemke 1990), and yet they still dominate the science classroom (Mercer, Dawes, & Staarman 2009; Wells & Arauz 2006). It should not, however, be forgotten that many ideas and theories have been developed over time and shaped by the results of dialogues and debates (Driver, Asoko, Leach, Mortimer & Scott 1994). Furthermore, the most recent guidelines on (inquiry-based) science teaching aim to highlight the authentic process of doing science, where:

- Learners are engaged by scientifically oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding
- Learners communicate and justify their proposed explanations. (NRC 2000, p.25)

At the heart of the modern interpretations of the guidelines presented above lies the idea that teaching and learning science is not only about learning the content, but also about learning how to develop scientific argumentation. In other words, a more epistemological approach towards science education encapsulates the idea of scientific knowledge being developed and shaped through critical dialogue over time, thus enabling the scientifically literate and enlightened student to evidence claims, state alternatives and establish the validity of such claims (e.g., Driver, Newton & Osborne 2000; Sadler 2006). In the reality of the classroom, however, science teachers tend to defer to scientific accuracy and use of correct terminology (Moje 1995; Munby, Cunningham & Lock 2000) rather than countenancing learners to share inchoate ideas along the way. Current and future demands, however, require more problem solving, critical thinking and understanding of scientific concepts. This concern, especially regarding the role of language and classroom communication in science teaching, is shared by an increasing body of researchers (Chin 2007; Lemke 1990; Mercer, Dawes & Staarman 2009; Mortimer & Scott 2003; Oliveira 2010a, 2010b). One of the central messages of the previous literature is that science learning should be more about construction of knowledge rather than collection of facts.

In order to destabilise the prevailing authoritative and monologic approaches in science classrooms an interventional teaching programme was designed to familiarize student teachers with the dialogic aspect of communication. The programme is introduced in detail in the Method section following a description of the background theory and research questions. A brief summary of the aims of the study is presented below.

1.2 Research aims

In response to the above-mentioned concerns regarding non-socially oriented and monologic science teaching, the aim of this study was to explicitly address the social dimensions of initial science teacher education. From this perspective, light is shed on student teacher communication during initial professional development. This development is realised firstly through increased awareness, leading subsequently towards more sustainable reformation of teacher practice (Desimone 2009; Kagan 1992; Pajares 1992). The rationale for developing teacher communication originates from learning theories emphasising the essential role of language as a mediator for learning. More specifically, communication that includes the dialogic aspect is argued to engage students in meaningful learning processes (Scott & Ametller 2007). In meaningful learning students' views are sought and valued as a part of the construction of scientific knowledge. Accordingly, reformation of teacher communication towards being more dialogic would ultimately be reflected in the development of students' reasoning and thinking skills, that is, development of learning.

In addition to the results concerning the teaching programme's impact on student teacher awareness and educational behaviour, the present study also provides new methodological innovations for mapping classroom communication. Within this study, besides considering discrete instances of exemplary communication, also the temporal development of classroom communication was carefully taken into consideration (Mercer 2008). This included presenting and interpreting different layers of classroom communication, such as episodic exchanges and turns taking place within them. The need to represent the temporal aspect of communication was also evident in the teacher education part of the study as student teachers struggled to conceptualise the different types of classroom communication. To this end, the visualisation of classroom communication offered a more dynamic and manageable approach to examining different communication types.

Before narrowing towards the conceptual framework and specific descriptions of classroom communication and presenting the specific research questions, some essential ideas within the sociocultural framework are briefly introduced in the following section.

2 THEORETICAL BACKGROUND

This chapter introduces some essential aspects of sociocultural theory. As the focus of this study is on only certain specific aspects of social interaction, the literature review of sociocultural theory has been kept relatively brief.

2.1 Introduction to the Vygotskian framework

In contemporary educational research, individual views of teaching and learning are considered to be insufficient for explaining the complex processes of classroom teaching and learning (Leach & Scott 2003). Arguably, the most essential achievements made with respect to reforming approaches to educational research and the evaluation of (science) teaching have been based on Vygotsky's (1978) elementary ideas about learning through interaction and communication. The sociocultural approach has guided researchers towards investigating the nature of interactions taking place in classrooms, rather than focusing merely on learning outcomes. The sociocultural perspective provides a framework for examining the link between language and learning and has become an increasingly popular approach among scholars in the field of education (e.g., Alexander 2006; Littleton & Howe 2009; Mercer 1995; Mercer 2000; Mortimer & Scott 2003; Reveles, Kelly & Durán 2007). Furthermore, the potentiality of sociocultural theory has also been acknowledged for science (e.g., Lemke 1990; Mortimer & Scott 2003) and mathematics education research (Solomon 2007). Conducting studies in science education through a sociocultural lens requires giving cogent theoretical weight to the role of social interactions taking place in science classrooms (Lemke 2001; Scott 1998). Whereas some researchers examine these interactions broadly in all their forms, others single out teacher talk as being the most powerful cultural tool available to the teacher in guiding students' construction of knowledge (Wertsch 1991). Similarly to the latter, the focus of the present study is on the verbal behaviour of the teacher, but in addition to this aspect the important role that student responses and initiations play in teacher-student interactions is also taken into account.

Continuing with the teacher-student interactional relationship, the concept of *scaffolding* (Bruner 1986) refers to educational activities in which the teacher helps the learner to achieve learning objectives by providing the right amount of support. Here, the teacher provides just enough assistance and guidance to help the student succeed, withdrawing whenever necessary in order not to do all the thinking for the student (Clay & Cazden 1992). The teacher should, for example, activate students' prior knowledge and break complex tasks down into easier, more manageable steps, thus reducing uncertainty and disappointment (McKenzie 1999). Framed differently, classroom dialogues should create a balance between challenging and supporting when addressing specific learning goals and tasks at hand (Ruiz-Primo 2011). Scaffolding could be understood either as a wider approach to education in general (macro-level) or as describing single educational activities (micro-level). Whereas the macro-level approach involves planning whole teaching sequences that are aimed at ultimately handing responsibility for learning over to the students themselves, the micro-level approach focuses on specific interactions, for example, between the teacher and the students (Sharpe 2008).

At the heart of Vygotsky's work lies the idea of the *zone of proximal development* (ZPD). Scaffolding takes place within the ZPD, which is defined as the zone encompassing the knowledge and skills that a child is able to gain if adequate guidance and tutoring is provided in the classroom by a knowledgeable figure, such as a teacher or more able peer. The ZPD could be considered as a dynamic framework within which interpsychological (cultural) processes transform into intrapsychological (individual) ones (Wertsch 1985). In other words, whereas multiple points of view are present on the social plane, individuals shape these views on the personal plane during the process of internalisation. Indeed, a crucial notion is that learning processes are not divided dichotomously as internal and external, rather they are interconnected. An essential aspect of this theory is how changes in interpsychological features might reveal development at the intrapsychological level. For instance, in the classroom setting, students' dialogues, questions and answers could reveal positive development in their thinking and understanding (Ruiz-Primo 2011). The associated concept of *appropriation* describes how individuals adopt intellectual or cultural tools in order to facilitate their own learning. The most essential cultural tool mediating learning, as emphasised also in this study, is classroom talk, often facilitated by the teacher. The present study also foregrounds the importance of the teacher developing a communicational environment in which learners have space to share their pre-existing views in order to access students' thinking more deeply.

Modern views: intermental development zone

Recently, other concepts have been derived to conceptualise the complex processes at play within the sociocultural framework. In the modern view, the

ZPD has been expanded to include more contributions of participants as initiators of collective discussions and meaning-making processes. When shifting towards dialogic interactions, in particular, Mercer (2000) introduces the *intermental development zone* (IDZ), which highlights the role of interactive dialogic contributions in keeping participants mutually attuned to the task at hand. The view of learning in the IDZ is acknowledged more as a product of social processes, whereas the ZPD addresses learning more on an individual level.

As mentioned above, in the modern view the zone of proximal development is not only for the teacher to create and maintain. Rather, this zone is created, shaped and maintained in collaboration with the participants (Wells 1999). Secondly, the zone of proximal development is not just something for cognitive activation and development; actions, identities and emotions are also shaped in the reciprocal environment created within the ZPD. The overall focus has been shifted towards collective descriptions of learning, thus bringing us back to the IDZ (Mercer 2000; Mercer & Littleton 2007), which emphasises the above notions of both the teacher and students creating contexts for making meaning. This idea is parallel with the concept of *community of practice* (CoP), which, in general terms, relates to collaborative settings in which colleagues and mentors share and reflect on their practice. However, the concept is equally applicable to classroom situations in which the teacher and students engage mutually in the tasks at hand and share their understandings through their interactions (Wenger 1998).

While the IDZ offers the potential to extend the development of individuals, at the same time it poses a danger. Its emphasis on student-student interactions raises concern regarding the quality of these peer communications. Some researchers have addressed this issue by introducing the concept of *exploratory talk* (Mercer, Dawes, Wegerif & Sams 2004; Mercer & Littleton 2007), which simultaneously highlights the mutual appreciation of peers as well as critical thinking with regard to the quality of content. Moreover, in exploratory talk the functions of language consist of explaining, asking questions, reasoning and stimulating thinking in terms of developing knowledge (Mercer 2000). However, without the appropriation of suitable talk-tools, there is a danger of non-constructive peer communication taking place.

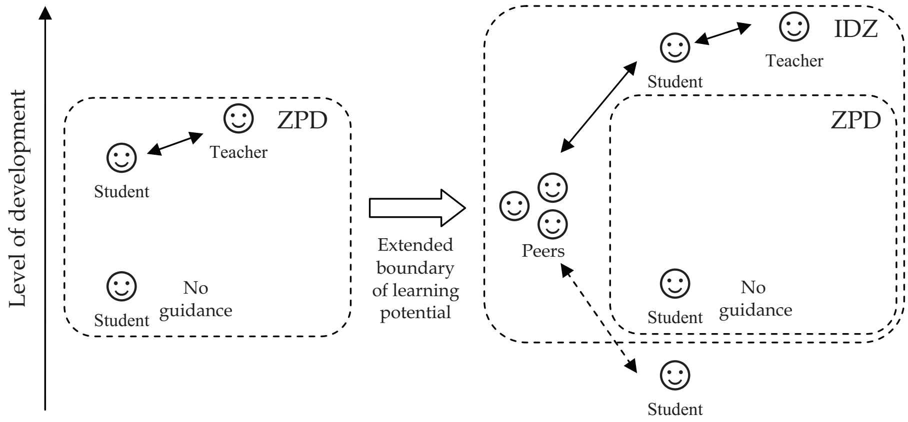

FIGURE 1 The extended boundary for proximal development. (→ = interaction arrow, --> = non-constructive guidance/collaboration)

Figure 1 illustrates the scenario in which the teacher constructively guides (scaffolds) within the zone of proximal development, thus elevating the individual student closer to their potential level of development. The left-hand side of the model is adopted and modified from the original illustrations of the ZPD and the right-hand side is based on the descriptions of the IDZ introduced above. In the extended boundary model both the teacher and peers can further increase the learner's level of development, but only if the peer interaction is constructive. Furthermore, when constructive, interaction with peers provides new scopes for acquiring and practising new learning and communication (social) skills. In this sense, the IDZ could provide greater "quality" in terms of dialogism, as different voices and ideas are appreciated as a part of the joint meaning-making processes.

However, according to Mercer (2000), if the interactions and dialogues are not constructive "the IDZ collapses" (p.141). Thus, in the worst case, non-constructive peer collaboration could even be harmful to the development of IDZ and student progress, at least in relation to learning goals. The student outside the IDZ in Figure 1 illustrates this undesirable situation of non-constructive peer interaction. Similarly, it has been discussed that active learning and its assimilation into peer activities do not necessarily result in student learning (Andrews, Leonard, Colgrove & Kalinowski 2011). On the other hand, dialogic learning activities, including the characteristics of exploratory talk, have been found to promote learners' critical thinking (Frijters, ten Dam & Rijlaarsdam 2008).

Having said this, it would be prominent that students adopt specifically beneficial discursive strategies to promote their in-depth learning (Gillies & Boyle 2008). To this end, the teacher plays a key role by leading by example and modelling constructive types of interaction, such as exploratory talk, and in this way preparing students for more collaborative and effective group work (Webb 2009). Resonating with this notion, preliminary evidence has been found that open-ended teaching approaches lead students more frequently to share both everyday and scientific ideas when justifying their claims during peer discussions (McNeill & Pimentel 2010). This suggests, therefore, that students, and even teachers, who have appropriated talk as a tool to mediate meaning-making processes are able to create, shape and maintain the IDZ.

When considering the relationship between the ZPD and IDZ, it has been proposed that the temporal frame of the ZPD "extends over a greater period of time than the IDZ" (Moate 2013). Deriving from this idea, in the present study it could be interpreted that teaching should take place within the ZPD more over the long term in order to reach higher levels of learning. Moreover, the ZPD could be expanded to the IDZ whenever students are given more responsibility for the learning processes. Figure 2 shows a modification of the extended boundary model (Figure 1) incorporating a time axis to represent the temporal relationship between the ZPD and IDZ. Whereas within the ZPD the teacher is required to approach teaching and learning from a broader perspective, the IDZ is created and shaped more spontaneously in-situ and in the moment by the teacher and students in collaboration.

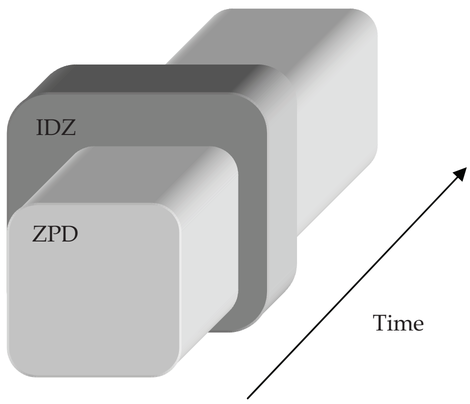

FIGURE 2 Expanded model for higher level of learning

As regards the IDZ, there is preliminary research addressing peer discussions in inquiry-oriented context in Finnish science classrooms (Hartikainen 2008). And, even though peer interaction is one of the most crucial forms of classroom interaction, the weight within this study is more on teacher-led interaction. Whole-class teaching, as the most common instructional approach worldwide, should be opened up to greater scrutiny due to its narrow communicational spectrum. More specifically, whole class discussions rarely offer students opportunities to authentically take part in the construction of knowledge (Myhill 2006).

2.2 Towards dialogic pedagogy in classroom communities

Although talk is a central feature of schooling and education and a growing area of educational research, there is still a substantial body of research that describes classroom talk as non-conversational (Alexander 2005). Based on empirical studies, there seems to be a gap between classroom realities and theories of learning and development that emphasise the importance of social interaction.

Beginning with studies supporting the features of dialogic pedagogy, the findings of Nystrand and colleagues (1997), for example, demonstrate that different styles of communication have different impacts on student learning. Despite this, student learning has often been associated with use of open questions (She & Fisher 2002). Nystrand and colleagues, however, warn against measuring the relationship between learning and communicative styles by focussing only on, for instance, the type of questions used over the course of a lesson (Molinari & Mameli 2010). Dialogic pedagogy is supported by increased use of authentic, topic-relevant questions on the part of the teacher, but more essential is the quality of the communication that surrounds these questions (Nystrand, Wu, Gamorgan, Zeiser & Long 2003). Not only talk, but also other features of interaction such as wait time should be considered when asking these kinds of questions (van Zee 2000; Chin 2004). In general terms, the most crucial consideration within dialogic pedagogy is how far the students are treated as active agents in classroom discourse, i.e. participants in the construction of their own knowledge (van Zee & Minstrell 1997; van Zee, Iwasyk, Kurose, Simpson & Wild 2001). This kind of approach is also considered to include a motivational factor, which is elemental to long-term activation of students (Hill 2000).

When discussing the relationship between discourse and the development of knowledge in schools, Wells (1999) presented the idea of *communities of enquiry*, in which the dialogic nature of discourse is exploited to enable knowledge to be co-constructed among students. According to Wells (1999), the relationship between teacher and students is dialogic in a sense, but is still "not a dialogue between equals" (p. 242). When planning classroom activities in advance, the teacher has leadership responsibility for selecting themes and associated activities related to the curriculum; but once student investigation is under way the teacher takes a more consultative role, modifying their support provision according to student progress. With regard to curricula, Wells and Arauz (2006) examined how the integration of inquiry approaches into curricula affected teacher communication. They found that there was clear evidence of an increase over time in the teachers' adoption of a "dialogic stance", although the initiation-response-feedback pattern was still pervasive.

The observed infrequency of dialogic interactions might result from communication in educational settings being driven by pre-determined and overloaded curricular content and objectives constraining the breadth of discussion and freedom of participants. Furthermore, teachers are bound by legal and contractual obligations. Teachers are mandated to limit students' speech, to assign tasks and to assess the quality of student activities. As teaching involves more pre-determined, narrow, precise and academic descriptions of phenomena in school science, it could lead ultimately to repulsion towards science subjects (Matusov 2011).

The different ways of interacting in the classroom community need to be understood in terms of their impact on providing or constraining student access to participation and opportunities for learning. Often students are left to navigate classroom interaction without any support or tools. As intimated above, classroom studies have found that elaborated talk does not simply occur when children are asked to undertake a task together (Mercer & Littleton 2007; Gillies & Khan 2008). The teacher's role is to support students in engaging in productive communication, to evoke ideas and views, and to model reasoning processes and, in this way, to enhance meaning-making and knowledge creation.

Moving towards more dialogic pedagogy requires of teachers the pedagogical skills to be able to follow and respond to the various processes taking place in the classroom. In addition to being aware of different ways of opening up *dialogic spaces*, teachers should also have the ability to shape these spaces with a view to achieving lesson goals, including, inevitably, the ability to set the boundaries for dialogue (Wegerif 2010). For instance, as inquiry-based approaches are increasingly integrated into school science curricula, teachers need to be more aware of how to open up authentic phases of inquiry and when to steer the discussion towards scientific conclusions. In general, teachers and teacher educators need to be educated in how to use different types of talk during teaching sequences for different teaching purposes.

The term dialogic pedagogy is generally used in reference to empirical settings and the actual implementation of dialogic pedagogy, although contemporary educational research also includes critical discussions on the theoretical and pedagogical implications of dialogic teaching. The following chapters present the key aspects of dialogic teaching covered by the present study.

2.3 Dialogic teaching

The term dialogic has been associated with a number of different types of classroom talk, such as exploratory talk, argumentation and inquiry. Consequently, there are contrasting views as to whether dialogic is understood to refer to forms of interaction in empirical settings or whether the theoretical implications of dialogic theory are taken into account. In this study, the aim was to take into account both empirical and theoretical aspects when integrating theory-based descriptions into practice, especially within the teacher education context.

Whereas the term dialogic pedagogy refers directly to the empirical context, dialogic teaching is often used in relation to theoretical descriptions. As previously noted, one of the general aims of this study was to proceed from a theoretical understanding of scholarly definitions of dialogic teaching provided in the literature towards the actual implementation of dialogic teaching in the reality of the classroom in the form of dialogic pedagogy. As this duality between theory and practice is already addressed in the literature (e.g., Al-Mahrouqi 2010), this discussion is not given detailed attention here. Instead, the core definitions of dialogic teaching and its related concepts are introduced before moving on to present the application of the conceptual framework.

The characteristics of dialogic pedagogy mentioned in the previous chapter can be classified according to the principles of dialogic teaching introduced by Alexander (2006). Alexander differentiates conversation from dialogue in terms of what follows from students' answers. In dialogic teaching, exchanges are linked into coherent lines of enquiry rather than left disconnected. Alexander's dialogic teaching includes the following five principles:

- *collective*: teachers and children address learning tasks together, whether as a group or as a class;
- *reciprocal*: teachers and children listen to each other, share ideas and consider alternative viewpoints;
- *supportive*: children articulate their ideas freely, without fear of embarrassment over "wrong" answers; and they help each other to reach common understandings;
- *cumulative*: teachers and children build on their own and each other's knowledge and experiences;
- *purposeful*: teachers plan and facilitate dialogic teaching with particular educational goals in view (Alexander 2006, p.28).

In general terms, dialogic interactions are defined as interactions where students ask questions, comment on ideas that emerge in lessons, explain and state points of view, and are given more time for thinking. Students need the support of the teacher who, in turn, must be sensitive to students' initiatives and able to use talk to provide continuity and ensure reciprocity. However, as Alexander (2006) points out, there is "a risk of confusion" (p. 119), as the term dialogic teaching has gained wider currency, for instance within science education research (e.g., Mercer, Dawes & Staarman 2009; Scott, Mortimer & Aguiar 2006). Within this study, the idea of dialogic teaching (and interaction) is contingent with Mortimer and Scott (2003).

Whereas Alexander (2006) sees dialogic teaching as applicable to the whole teaching process, in which dialogue builds on previous contributions and is targeted in a specific direction, Mortimer and Scott (2003) make a clearer distinction between different approaches constituting communication in the science classroom: the distinction between authoritative and dialogic *communicative approaches*. In this sense, the teacher can either base their communicative approach on taking different voices and ideas into account, in this way adhering closely to the core characteristics of dialogic teaching, or they can lean more authoritatively towards the scientific point of view in order to steer learning in the desired direction. In both cases, the teacher will, ideally, nurture sociocultural principles as well as the essential role of language in learning.

In some interpretations there seems to be a theoretical contradiction between the sociocultural and dialogic views of learning. The sociocultural approach can also be viewed as parallel to so-called "dialectic" learning, in which learners aim collaboratively to establish the knowledge to be learned. In contrast, according to the dialogic view (Bakhtin 1986) different perspectives are made mutually available without fear of being right or wrong (Moate 2011; Wegerif 2008). In dialogue, everyday and scientific voices are equally present, thus enabling authentic creativity, imagination and problem solving, which are fundamental to the development of scientific knowledge (Driver, Asoko, Leach, Mortimer & Scott 1994). Conversely, in dialectic processes the emphasis is more on goal-oriented learning, and although collaborative, interactive and reciprocal, the learning processes do not necessarily foster sufficient openness to accommodate diverging ideas, thus conforming more to a dialectic than dialogic approach. Indeed, upon reflection, it may seem that the goal orientation in Alexander's teaching resonates more with dialectic rather than dialogic thinking. Controversially, within the Mortimer and Scott (2003) framework, dialogic communication is emphasised as having its own space in classroom discussions, within which different, authentic and even inchoate ideas may emerge, these being addressed more authoritatively only at a later stage.

The above clarifications are also essential with regard to the present work, since although the term dialogic is emphasised throughout this study, it is understood that meaningful science teaching consists of the teacher opening up spaces for different views and being able to benefit from these discussions when subsequently moving towards scientific conclusions via a more authoritative approach (Scott & Ametller 2007). Reflecting on the above notions, dialogic and dialectic (authoritative) processes should both be present in meaningful science classroom communication. As indicated, the specific emphasis on and need for both of these aspects originates from the nature of science and the scientific disciplines. Therefore, the objective within this study is not to view teaching solely as dialogic, rather teaching should develop towards being *more* dialogic. Furthermore, the discussion around dialogic teaching in this study refers more to pedagogy than specifically theoretical conceptualisations of dialogicality.

Based on an examination of the different aspects of communication, the temporal concept of *cumulativity* is applied further in this study (see especially Article I). Cumulativity is not just about addressing how peers build on each other's utterances (Mercer 2000), but rather, according to more recent definitions, it addresses how the teacher builds on learners' contributions (Alexander 2006; Mercer 2008) and, as highlighted in the present study, how this is done via versatile activities and communication. In inquiry-based learning, cumulativity relates to taking into account students' initial everyday experiences and linking them with more scientific explanations, thus fostering progressive development of learning trajectories in and out of the classroom context (Littleton & Kerawalla 2012; Ludvigsen, Ingvill, Rasmussen, Krange, Moen & Middleton 2010). In other words, as elaborated by the Littleton and Kerawalla (2012) study, the consideration of cumulative quality involves exploration of "…how connections are made between ideas and settings over time" (p. 31). More specifically in this study, cumulativity is considered to be a necessary element for creating connections between the different communicative approaches linked to specific teaching purposes and activities.

The cumulative aspect of teaching is generally considered difficult to achieve (Alexander 2005) as it requires of the teacher a high level of professional skill, including genuine subject knowledge, appropriate pedagogical skills and understanding of the capacity of each child, in order to take learners' thinking forward. As referred to earlier, making use of students' own prior knowledge and efforts has been discussed as being one of the key elements of progressive learning (Myhill & Brackley 2004). Correspondingly, cumulative talk can be related to so-called *accountable talk*, which is characterised as responding to what has been said and further developing what peers have said (see Sohmer, Michaels, O'Connor & Resnick 2009). More generally, the principles of accountable talk go parallel with the general principles of dialogic teaching.

Overall, the concepts underpinning the salience of dialogic pedagogy in classroom practice call for teachers to engage in productive meaning-making processes by planning tasks that generate dialogue between children and teachers. At the heart of these scholarly definitions is the aim of softening the edges of the asymmetry in speaking rights (Cazden 2001). More specifically, this means not only allowing students to take turns without teacher control, but also giving students the right to express themselves freely and to be wrong. Students should be entitled to take a more active vocal role in the classroom. Exploratory talk, for instance, has been found to promote the individual and group reasoning and argumentation abilities of students (e.g., Rojas-Drummond & Mercer 2003; Mercer & Littleton 2007). These kinds of approaches aimed at probing student thinking and understanding challenge the power relationships of the classroom and nurture student engagement, confidence, independence and responsibility (Alexander 2006). However, as previously indicated in the introduction, environments that promote child learning can be realised only with the structured guidance of teachers (Littleton & Mercer 2009).

2.3.1 The conceptual framework in relation to dialogic teaching

The above sections provided a brief introduction to the concepts derived from the sociocultural perspective of teaching and learning, as well as a general overview of the principles of dialogic teaching described in the literature. We have seen how the sociocultural view highlights the crucial role of spoken language, while dialogic theories frame the general ideology for mutual consideration of different voices, views and ideas in science classrooms.

One way of gaining a more holistic and realistic view of the complexity of classroom communication is to combine different research methods (Barnes & Sutherland 2010). While this aspect is addressed at a general level by the present study, the study by Mortimer and Scott (2003), in particular, offers a unique concept with which to effectively examine teacher-student communication. The concept is used in each of the articles as a basis for categorising teacher-orchestrated communication. After introducing the concept of communicative approach, question types and scholarly definitions of the common communication patterns occurring in classrooms are introduced by discussing their relation to communicative approaches.

The concept of communicative approach

This framework differentiates the typical transmission modes of teaching from classroom interaction where students are given the freedom to, for example, describe, compare, classify and argue when taking part in discussions. Mortimer and Scott's (2003) framework for describing classroom discourse consists of four categories generated from the combination of two dimensions: interactive/non-interactive and authoritative/dialogic. *Interactive* talk allows students to participate, whereas *non-interactive* talk is of a lecture type; and whereas the *dialogic approach* takes account of diverging ideas, the *authoritative approach* focuses on a specific point of view, usually the scientific view, controlled by the teacher:

- In the question answer routine of the *interactive authoritative* approach, students' responses are often evaluated and the teacher neglects diverging ideas. The authoritative approach focuses on the scientific point of view.
- In contrast, the *interactive dialogic approach* explores and exploits students' ideas (e.g., everyday views), and has no evaluative aspect. Thus, the dialogic approach, in Mortimer and Scott's categorisation, is considered when the teacher is not trying to achieve a specific point of view. Rather, the teacher tries to elicit the students' points of view and works with these contrasting views.
- In the *non-interactive authoritative* approach, the teacher presents scientific content by lecturing and takes no account of contrasting points of view.
- In the *non-interactive dialogic* approach, the teacher works with contrasting points of view, such as students' everyday views, and moves on to present the scientific view. Thus, even though the teacher is lecturing, diverging ideas are discussed. The teacher talk is therefore dialogic by nature.

Scott and Ametller (2007) stress that meaningful science teaching should include both dialogic and authoritative aspects. For example, if discussions are *opened up* by a dialogic approach to allow students the opportunity to discuss different ideas, at an appropriate point the discussion should also be *closed down* via an authoritative approach. This closing down-phase is considered essential for enabling the teacher to intervene and clarify the differences between the students' everyday views, which my fall far short of providing a satisfactory explanation, and the accepted scientific explanation, thus bridging the gap between the two (Eshach 2010; Mortimer & Machado 2002). These two phases are explicitly included in the model of dialogic inquiry-based teaching (see Article III).

In addition, the two phases of opening up and closing down could also constitute the cumulative structure for classroom communication. Once again, whereas dialogic teaching stresses the dialogic and social aspect, scientific knowledge necessarily includes the authoritative side of communication and should not be neglected as a part of meaningful learning of science. As the dashed line between authoritative and dialogic approaches in Figure 3 indicates, there is a fundamental tension between these two approaches with each communicative approach giving rise to the other (Scott, Mortimer, & Aguiar 2006). This characteristic is acknowledged in this study and the dichotomous categorisations applied in the analysis are given substantial rationale in the individual articles in terms of coding categories.

	Interactive	**Non-interactive**
Authoritative focus on the science view	Presentation Question & Answer routine IRF	Presentation Lecture
Dialogic different points of view are considered	Probing Elaborating Supporting I-R-F-R-F	Review

FIGURE 3 Communicative approaches with teacher interventions and the common patterns of talk. (Figure adapted from Mortimer & Scott, 2003)

It should be noted that the communicative approach does not consist of a single sentence or a teacher-student exchange. A communicative approach consists of a series of teacher-student exchanges that should align with the specific teaching purpose. Thus, the analysis of communicative approaches involves careful consideration of the prevailing types of teacher-led talk or chains of teacher-student exchanges. In other words, sequential patterns constitute episodes within a certain communicative approach. Applying a temporal scale to the episodes supports the identification of communication structures that characterize the overall communicative approach of the teaching sequence.

The patterns of talk

The patterns of talk, as introduced in Figure 3, are the result of significant groundwork conducted in recent decades on discourse in science (Lemke, 1990). According to Lemke and many other scholars (Driver, Asoko, Leach, Mortimer, & Scott 1994; Mortimer & Scott 2003; Bleicher, Tobin & McRobbin 2003), the essence of science learning is learning how to "talk science". Lemke refers to the typical form of science teaching as a triadic dialogue where the initiation of the teacher is followed by the response of the student, which is followed again by feedback from the teacher. This form of talk is also known as the IRF pattern of discourse, where *I* stands for the *Initiation* of the teacher (such as a question), *R* for the *Response* of the student and *F* for the *feedback* (or *follow-up*) of the teacher (Sinclair & Coulthard 1975). Whenever teacher feedback is evaluative, the pattern can be written as IRE, where *E* stands for *Evaluation* (Mehan 1979).

In particular, the features of the F move that extend beyond evaluation have been discussed as being essential for activating student thinking and reasoning processes (Cullen 2002; Nassaji & Wells 2000). Since it is estimated that far more than 50% of teaching follows the triadic pattern, it would be beneficial to examine any variations of this pattern that might promote dialogic interaction. This is one of the key interests of the present study of science classroom communication. This communication cannot, naturally, be properly evaluated by merely examining individual events or turns facilitated by the teacher; instead, the focus of this study is also on the communicational entities that constitute the different communicative approaches used.

As touched on earlier, the IRF sequence prevalent in science classrooms limits students' opportunities to share their everyday views, and consequently its current level of use is increasingly considered to be excessive (Lemke, 1990). In addition to Lemke (1990), Rojas-Drummond and Mercer (2003) also argue that excessive use of the common IRF pattern should be discouraged. As Chin (2006, 2007) states, also questions should be of the kind that promote students' reasoning skills rather than position students merely as reproducers of knowledge. The question types are presented later in this section.

Another more recently described distinct talk pattern is the IRFRF chain in which student responses are followed by the teacher directing the turn back to the pupils without evaluation. For instance, the teacher might elicit students' points of view without evaluating their responses, instead prompting[1] the students for further thinking. This pattern could be related to the so-called "spiral" IRF exchange constituting a sequential IRF pattern (see Berland & Hammer 2012), fostering more interactive, collaborative and supportive

[1] Scott, Mortimer and Aguiar (2006) refer to an IRPRP chain, where *P* stands for *prompt*.

learning (Rojas-Drummond, Mercer & Dabrowski 2001). The increased prospectiveness of teacher follow-up within the spiral IRF pattern offers the potential for the development of authentic dialogic interaction (Sharpe 2008; Wells 1999). In contrast, if the teacher is merely renegotiating towards the correct answer and closure, the authoritative approach is being applied and the talk follows an IRF pattern with evaluative feedback ("loop" IRF). In other words, sequential IRE exchanges should not be considered as a dialogic approach. As previously noted, although patterns of talk are strongly related to the specific communicative approaches introduced earlier (see Figure 3), discrete patterns of talk cannot be solely relied on to identify a communicative approach.

Question types

Questions are often defined as either closed or open. The type most associated with initiating and indicating dialogic interaction is the *open question* (Chin 2007). *Closed questions* rarely lead to dialogic interaction; instead they aim for pre-defined answers and offer no flexibility with respect to the student's response. Open questions, on the other hand, elicit something from the student, such as explanations or predictions. Open-ended questioning is also closely related to "real" (Furtak & Shavelson 2009) or "authentic" questioning (Nystrand et al. 1997) where the answer is not necessarily known or expected by the teacher. Open questions aim to stimulate, explore and prompt students' thinking beyond merely memorising facts. Furthermore, open questioning has been associated with better learning outcomes and positive attitudes towards learning science (She & Fisher 2002). However, as mentioned earlier, more essential with regard to fostering dialogic discussion is the nature of the interaction surrounding these questions over time. In addition to teacher initiations, dialogic discussion can also be initiated by student comments or *wonderment questions* (Aguiar, Mortimer & Scott 2009; Ruiz-Primo 2011), or following an incorrect answer to a closed question. Another indicator of a possible dialogic approach is the use of *wait time* following questions. Students need to be allowed enough time to formulate responses to the kinds of questions that require thinking and reasoning (Chin 2004; Sohmer et al. 2009), which are in themselves indicative of dialogic teaching.

The above-mentioned indicators, such as open questions or students' wonderment questions, can be considered as potential dialogic tools for opening up dialogic discussion. In other words, open questions and wait time serve to open up dialogic spaces (Wegerif 2007) and can be understood as symbolical tools for fostering the implementation of dialogic teaching. A modern example of a physical dialogic (cultural) tool is the increasingly popular interactive whiteboard (Gillen, Staarman, Littleton, Mercer & Twiner 2007; Kershner, Mercer, Warwick & Staarman 2010). Kershner and colleagues (2010), however, emphasize that an interactive whiteboard itself cannot engage in collaborative learning if teachers and students are not aware of the talk rules (such as exploratory talk) supporting this kind of learning environment.

Exploratory talk

The description of exploratory talk overlaps partially with Alexander's dialogic teaching (Mercer & Littleton 2007; Littleton & Mercer 2009). The major difference is that exploratory talk involves students engaging *critically* (yet constructively) with each other's ideas. These definitions go hand in hand with the principles of argumentation in which students are prompted to confront, explain, defend and reframe their views (Asterhan & Schwarz 2007; McNeill & Pimentel 2010; Sadler 2006). As stated by Berland and McNeill (2010), during authentic argumentation "all participants have the opportunity to question, evaluate, and challenge ideas" (p. 781). These ideas also apply to the kind of dialogic inquiry-based teaching and, especially, student-student interaction that the teacher should embrace during the inquiry phase.

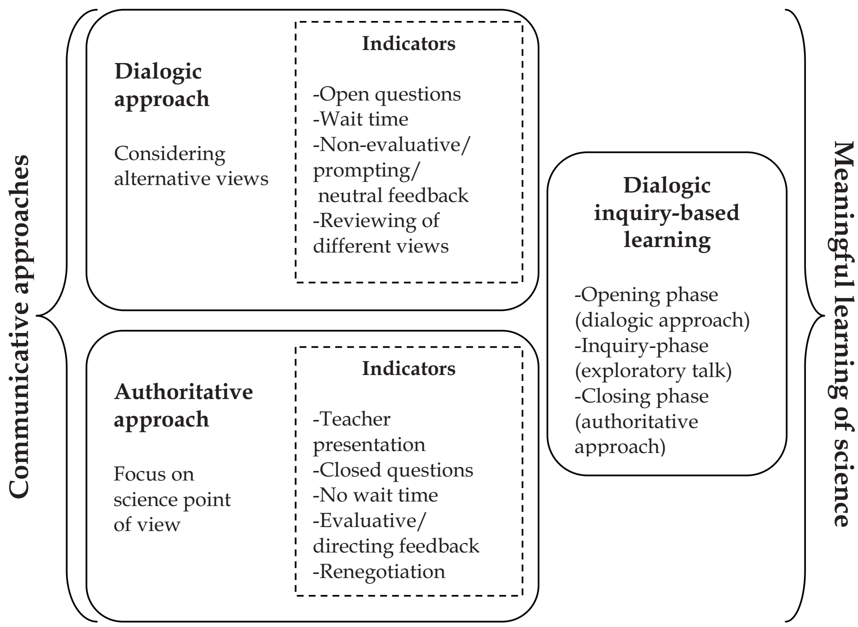

FIGURE 4 A framework for meaningful learning of science

Summary

To summarise the main concepts, within this study Alexander's dialogic teaching is understood as an overall ideology embracing the educational resources students' contributions can offer to more motivational science learning through dialogue. Mortimer and Scott's dialogic approach, on the other hand, is considered as just one of the communicative approaches that may be "best suited for the occasion" (Mercer & Littleton 2007, p. 48). One may ask, for instance, whether a non-interactive dialogic approach resembling monologue/lecturing fulfils the principles of reciprocal and collective dialogic teaching, yet, on the other hand, this approach is unparalleled in making purposeful connections between different views and making explicit the cumulation of ideas. Furthermore, although the dialogic dimension of classroom communication is emphasised in this study due to the prevailing absence of dialogue in the classroom (Mercer, Dawes & Staarman 2009), authoritative approaches are nevertheless considered an essential part of meaningful learning of science (Scott 2007; Scott & Ametller 2007). The framework for meaningful learning of science is illustrated in Figure 4.

The concept of the communicative approach offers a unique and more concrete way of interpreting and understanding different types of instructional communication. Moreover, it provides a useful framework that can be adapted for the analysis of classroom communication and can also be considered as a theory-based planning tool (Mortimer & Scott 2003). In addition to these applications, in this study the communicative approach was used in the student teachers' reflections on their own video recorded lessons. This is described in more detail below in the description of the teaching programme on teacher talk (especially Article II).

2.3.2 Dialogic teaching and inquiry-based learning

One of the aims of this study was to examine how the general principles of dialogic teaching and inquiry-based teaching can be combined (Articles III and IV). The concept of dialogic inquiry-based teaching thus derived originates from the notion that the meaningful learning of science necessarily includes both authoritative and dialogic aspects of communication. As the concept of dialogic inquiry-based teaching is introduced in detail in the articles, the inquiry-based approaches and the rationale for the dialogic aspect are presented here as a general overview.

As mentioned in the introduction, inquiry-based approaches have gained increasing popularity in science teaching and professional development programmes (e.g., Akerson & Hanuscin 2007; Luera & Otto 2005), especially since being outlined in the US National Science Education Standards in 1996 (NRC, 1996). One limitation of these programmes is that they tend to overlook the dialogic aspect of inquiry-based science teaching. Instead, they focus on other aspects such as designing appropriate lessons, adopting effective teaching methods, following particular instructional activities, and evaluating student learning. In addition, professional development programmes are often based upon lectures and transmission of knowledge and lack integration into instruction (Abell 2000), thus failing to access student teachers' pre-existing needs for professional development (Chval, Abell, Pareja, Musikul & Ritzka 2008). Moreover, despite inquiry-based teaching having been increasingly integrated into curricula, the ways in which these approaches are implemented in practice should also be taken into account more extensively already during initial teacher education (Fazio, Melville & Bartley 2010).

Although the guidelines for inquiry-based approaches relate in many ways to dialogic teaching, the descriptions used (e.g., teacher as a guider or co-inquirer) are often uninformative when it comes to a deeper understanding of the complex interactions occurring in inquiry-based science classrooms (Oliveira 2009, 2010a). Furthermore, there is concern regarding the openness of inquiry, which too often follows a predetermined pattern of discovery in which students work according to a formula towards a desired outcome (Sadeh & Zion 2009). It is also crucial that students acquire more open discursive communication strategies as the dynamics of peer discussions can readily lead to traditional authoritative communication within groups (Oliveira & Sadler 2008). This should not be the case within authentic inquiry.

As regards the possible shortcomings of inquiry-based approaches, it has been stated that extensive use of student work does not necessarily equate with better learning outcomes (Abrahams & Millar 2008). Science experiments are typically conducted following a simple "cook book" approach in which pre-defined steps are executed, thus leaving no space for authentic inquiry (Saari & Sormunen 2007). In addition, PISA reports have shown negative correlations between the use of inquiry and debate and student performance, which could be a reflection of the current poor quality, or simply absence, of authentic scientific inquiry (OECD 2007). This calls for explicit structure to be brought to vague descriptions of inquiry-based teaching methods and, specifically, the types of communication involved.

Although features of authentic inquiry are included in today's curricula, the ways in which science experiments are conducted in the classroom are still much more representative of a constructivist view of learning with the social aspect of doing science almost entirely lacking. Since experimentation is an essential part of the Finnish comprehensive core curriculum and that of many other countries (Pehkonen, Ahtee & Lavonen 2007), the ways and extent to which experiments are implemented within inquiry-based practices should be given further attention in research. However, although experiments were included in the study data, the primary starting point was to examine teacher-student communication and how the teacher takes account of students' observations and emerging ideas and elaborates these while remaining in keeping with overall lesson goals. Thus, the focus was not so much on how students conduct experiments, but rather how the teacher takes the students' contributions into account via different communicational approaches.

3 RESEARCH QUESTIONS

The research aims of this study originate from the presented background theory. Drawing on a sociocultural rationale for evaluating classroom interaction, the current trends of prevailing authoritativeness and monologic forms of communication foreground the need for more dialogic pedagogy in science classrooms. While all four articles examine the dialogic aspect of science teaching, each article has its own specific focus and participant group. The initial focus was on in-service teachers' practice with the aim of determining the dialogic status and further exploring dialogic cases contextualised by classroom realities. The focus was later shifted towards the examination of case examples of versatile communication, which offered potential for further theory development. In addition, the "social gap" in teacher education (Oliveira 2009, 2010a) was addressed by executing a teaching programme promoting goal-oriented and versatile communication with a focus on the dialogic aspect.

To obtain a view of the current communicational status of science classroom practice and as a comparison for initial student teacher practice, an international video study between Finland, Germany and Switzerland, the QuIP (Quality of Instruction in Physics) project, opened up a fruitful opportunity to study physics teachers and the communicative approaches used during lessons on the topic of electrical power and energy. Once the absence of dialogicality became evident, a more qualitative research approach was adopted. More specifically, instead of examining only to *what extent*, the aim was to explore *how* dialogic interactions manifest in science classroom realities. Teachers who used varying communicational approaches were examined further in order to *identify the specific structures of communication, including the dialogic aspect*. As noted earlier, as dialogic interactions proved to be extremely infrequent, the examination became increasingly focused on exemplary cases rather than highlighting the absence of dialogic interaction.

Alongside examining science classroom communication, the PhD project included planning and implementing an intervention, a teaching programme that would give the researcher, as well as physics/primary school student teachers, an opportunity to research student teachers' educational behaviour, particularly with regard to use of talk, during their initial teacher education. Interest was especially focused on *how student teachers adopt the theory of dialogic teaching into their views and practices during their initial teacher education* within the designed teaching programme.

Briefly, this study addresses the following main research questions derived from the rationale presented above:

1) How do dialogic interactions manifest in the science classroom? (case example, Article I)
2) How do student teachers adopt dialogic teaching into their views about science teaching? (Articles II & III)
3) How do student science teachers implement dialogic teaching during initial teacher education? (Articles II & IV)

Although each of the four articles has a specific focus, they are interlaced in terms of examining how dialogic interaction can be adopted to achieve more versatile science classroom communication. Both teacher education and the in-service context are covered when discussing the implementation of more dialogic pedagogy. Thus, it is considered that the four articles included in this dissertation substantially cover these two parallel dimensions, which comprise the following groups with different backgrounds: science student teachers, primary school student teachers, and in-service science teachers. This study does not access the longitudinal dimension of investigating the development/regression of student teachers in service, rather the focus is merely on the development during teacher education. The longitudinal aspect would, however, be an essential area for further research, and some key challenges for long-term dialogic reform are highlighted in the discussion section.

Research question 1 is addressed in Article I, the aim of which was to seek and explore dialogic interactions in science lessons executed by voluntarily participating secondary school teachers. Whereas the main international study was quantitative by nature, the study conducted within this dissertation addresses whole-class teaching sessions of Finnish teachers more qualitatively. Firstly, all teachers were examined in order to determine the extent to which their initiations emerge as dialogic episodes fulfilling the criteria for educationally meaningful science learning. As the research focus was refined, those teachers whose practice showed clear signs of a dialogic approach were selected for further examination in order to identify specific *communication structures*. Finally, the expected infrequency of dialogic interaction steered the research towards a case study in which one teacher who was found to implement a *cumulative communication structure* was explored further in order to demonstrate how the case example fostered meaningful learning of science. Briefly, Article I contributes to temporal research of classroom communication by examining *how talk develops over time*.

Research question 2, addressed in Articles II and III, sheds light on physics and primary school student teachers' views on the dialogic aspect of classroom communication. While Article III focuses on conceptions of dialogic teaching and inquiry-based learning, Articles II and IV contribute also by providing preliminary evidence of how intentional planning of communicative approaches affects student teachers' lessons. The implementation part of the study covers *Research question 3*.

The three main research questions come together in providing general information about the current dialogic status as well as in presenting innovative remedies for educating more dialogically-oriented teachers in order to help bridge the expected and observed dialogic gap in the classroom. From the outset, the dialogic aspect was practiced during initial implementation (see Figure 5). In addition, although the weight is more on the teacher education context, Articles I and II also provide an opportunity to discuss the similarities/differences between prospective teachers' and in-service teachers' communication, which is given further attention in the general discussion section of this dissertation. The objectives of Articles III and IV conform closely to Article II and expand dialogic teaching to the context of inquiry-based learning and primary school student teachers.

All of the articles are recommendable reading for those with an interest in dialogic teaching. Methodologically, Articles I, II and IV provide further developed approaches to the analysis and interpretation of classroom communication. These approaches include utilising *visual presentations* of *overall communication*, which is a somewhat novel approach. Article III focuses on primary school student teachers' conceptions of inquiry-based teaching including the dialogic aspect, and student teachers' learning concerning these concepts.

Briefly, the theory development in the articles consists of collecting, combining and developing ideas existing in educational literature about dialogic teaching and teacher talk. Seminal ideas include, for example, illustrations and descriptions of specific communication structures and theory-derived criteria for dialogic inquiry-based teaching. As mentioned, Article I provides more insights into the temporal aspect and the *temporal properties of teacher talk*. Consideration of the *dynamic aspect* of classroom communication is given by illustrating via *communication graphs* how talk develops over time.

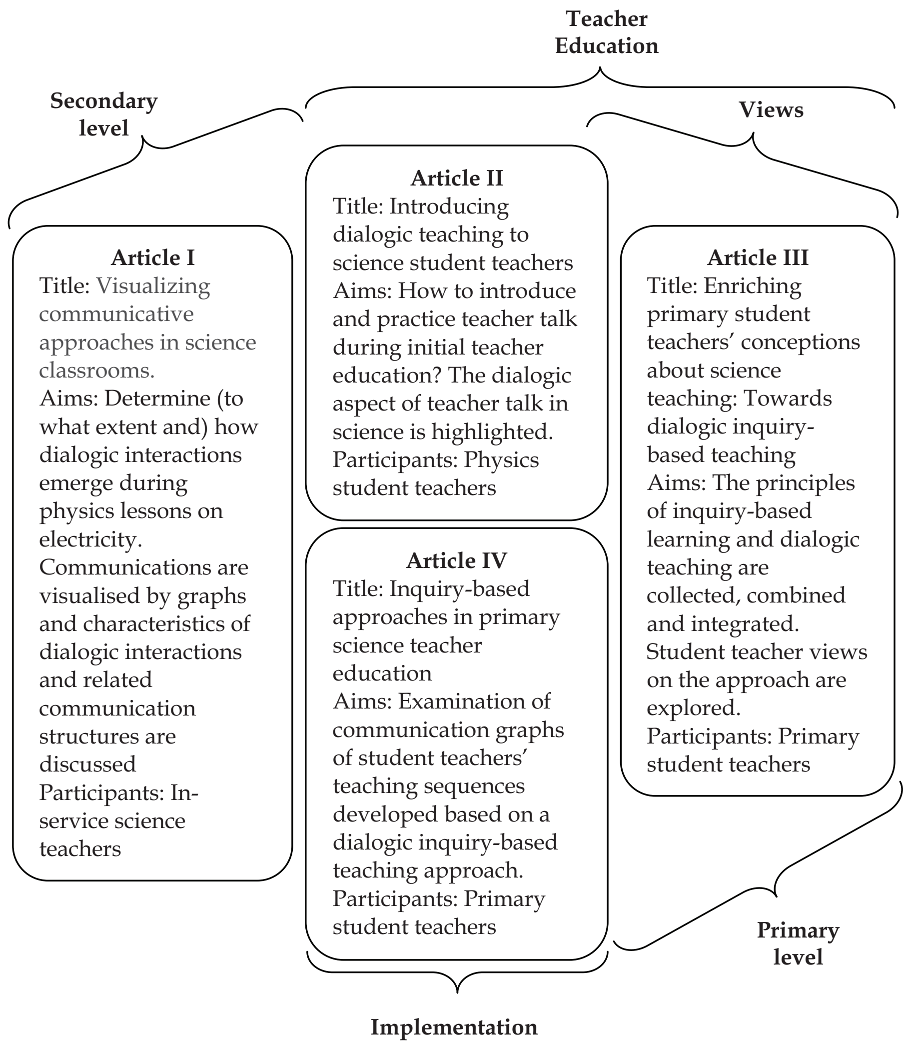

FIGURE 5 Descriptions of the articles and their relations

4 METHOD

4.1 The context

The research was carried out in both pre- and in-service settings. The participating student teachers conducted their pedagogical studies at the University of Jyväskylä and the in-service teachers at their posts in secondary schools in central Finland. The research participants are described in more detail in the corresponding articles. The following sections will therefore focus on the context of teacher education and the grounds for teacher professional development.

4.1.1 Teacher education in Finland

In Finland, the responsibility for providing initial teacher education to prospective primary and secondary teachers was transferred to universities over three decades ago. At the same time, subject teacher training was also reformed to include more pedagogical studies in order to raise educational standards in subject teacher education (Jakku-Sihvonen & Niemi 2006).

Primary school teacher education

Studies in primary school teacher education last approximately five years. The qualification includes, for example, language and communication studies, major subject studies, school pedagogy, minor subjects and elective studies. In total, qualification requires 300 ECTS[2] credits. This is the minimum amount for a Master's degree, also for secondary school subject teachers.

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2 Bachelor's degree consisting of 180 ECTS credits continued to Master's degree with 120 ECTS credits

Since physics and chemistry have been recently included in the primary school curriculum as separate subjects (FNBE 2005)[3], there is increased interest in physical and chemical sciences in primary school teacher education. As regards preparing teachers for teaching science in primary schools, there are, however, no obligatory or standardised courses, rather universities provide a range of science courses addressing subject pedagogy as well as subject contents. At the primary school level, for instance, three main physics themes are covered: energy and electricity, scales and structures, and substances around us. An example course for primary school student teachers including both content and pedagogical aspects is introduced in Articles III and IV. These articles introduce the dialogic inquiry-based approach to science teaching and include multidisciplinary content (physics, chemistry, geography, biology etc.) and educational theories such as dialogic teaching. The inquiry course addressed a wide range of topics related to climate change and global warming from both physical and geographical perspectives.

Secondary school teacher education

Today, there are two options in the education of secondary school teachers. Majority of student teachers finish their Bachelor's degree in their chosen subject first and apply separately for teacher education. Some choose to apply directly for science teacher education when applying to study in university. The direct selection procedure is nowadays more recommendable option in terms of the development of teacher identity. This option is preferred when prospective students know they are heading for the teaching profession.

Whereas primary school student teachers are students of the faculties of education, responsibility for subject teacher education lies partly with the Faculty of Education and partly with the faculties of the different teaching subjects. Thus, secondary schools' subject student teachers are students of the department of their main subject. For example, physics student teachers belong to the department of physics. Subject teacher education in science includes studies in one, two or three teaching subjects plus the teacher's pedagogical studies as part of a Master's degree. A teaching subject means a subject that is included in the lower or upper secondary school curriculum. In lower secondary school (grades 7-9) mathematics, physics and chemistry teachers often teach all three subjects and, in many cases, are also responsible for teaching information technology. In larger schools, upper secondary school teachers may teach their main subject exclusively.

[3] Some contents were included in the school subject of environmental and natural sciences before physics-chemistry and biology-geography were separated as their own subjects in 2004.

General objectives of teacher education

The general aims of educational studies include the development of ideas of holistic human development, teacher/student interaction, and scientific theories of education. The application of theory is also mentioned as one of the general objectives of current and, especially, forthcoming teacher education, which supports the pragmatic approach (Lefstein 2006) and is in accordance with the aims of the present study. This is also in line with the policy of the Finnish National Board of Education, according to which theory should be increasingly integrated with actual teacher practice. In addition to this, teachers should be also prepared as researchers of their own profession in order to lay the groundwork for future collaboration with scholars in the field of education (Opetusministeriö 2007; Jakku-Sihvonen & Niemi 2006).

The educational studies are intended to provide student teachers with the pedagogical requirements for independent practice in comprehensive schools, upper secondary schools and other educational institutions. The main objective is for student teachers to develop as autonomous professionals and members of their working community. The pedagogical studies are conducted at the department of teacher education in the faculty of education. With the exception of a few weeks of in-service training, all teacher education is conducted within the teacher training school under the supervision of teacher tutors.

The university teacher training school is an authentic comprehensive and upper secondary school environment following the national curriculum. The teacher tutors serve as teachers in the teacher training school, executing classroom lessons as well as supervising the student teachers and having overall responsibility for the teacher training courses. Each student teacher executes approximately five lessons per course, and a total of around 20 lessons, minor subjects included. The student teachers' lesson plans are subject to prior approval by their teacher tutor, who also provides feedback on teaching performance. Teacher tutors are required to have a Master's degree in their main subject as well as approximately two years of teaching experience.

The structure and form of the Finnish national curriculum for primary and secondary schools makes no specific provision for teacher's transitioning from the heavily theoretical initial teacher education phase to the reality of the classroom. Teachers must therefore have from the outset the skills necessary to be able to operate autonomously and create their own teaching plans. Since the curriculum provides no detailed guidelines concerning class content or teaching methods, the onus for planning and implementing lessons is with the teacher. Teachers thus usually rely on textbooks and teacher's manuals (Sánchez & Valcárcel 1999), although, in principle, (subject) teacher education is supposed to provide the student teachers with the necessary subject knowledge (content knowledge) and pedagogical knowledge (both general and pedagogical content knowledge).

The topics of teacher talk and different discourse type categorisations have been addressed as part of subject teacher education. However, these have been introduced as part of general methodology instruction, which is directed to all science teachers. Thus, explicit and individual practising the categorisation and implementation of different communicative approaches has remained lacking from teacher education. In the teaching programme introduced in detail in Article II, however, the concept of communicative approach was introduced to the volunteer participants over the year-long teacher education period. The social and dialogic aspects of teacher talk, in particular, were emphasised and practised explicitly.

4.1.2 The teaching programme

The approach of the teacher education part of the study was empirical and can be considered to address two key aspects: the effects of teacher education and of design research (Borko, Liston & Whitcomb 2007). Regarding the first aspect, the aim was to determine how the exemplary intervention on teacher talk affected the orientation and implementation of student teachers' instructional talk during their initial teaching experience. The design research aspect comes into question in the teacher education part of the study, since the goal was to design and implement educational opportunities for student teachers and to assess the teachers' development in the context of those opportunities.

The teaching programme addressed the teacher education part of the study. The programme was fully executed in subject teacher training during two separate academic years (2007–2008 & 2008–2009) and was also partly adapted for primary school teacher education. Whereas with subject teachers the teaching programme was integrated into the teacher training curriculum, primary school student teachers were introduced to dialogic teaching through a course focusing on inquiry-based teaching and learning. The designed teaching programme on teacher talk is introduced more specifically in Article II and related publications (Lehesvuori, Viiri & Scott 2009; Lehesvuori, Viiri & Rasku-Puttonen 2010), while the focus in this dissertation is more on the background and rationale of the programme.

Although the quality of initial teacher education, especially in Finland, has been widely praised (Pehkonen, Ahtee & Lavonen 2007), in general concern has been raised that many teaching programmes lack professional experience of the use of different teaching approaches, which is considered essential for professional development (e.g., Clarke & Hollingsworth 2002; Borko 2004). Student teachers often lack the ability to effectively put into use the appropriate pedagogical strategies covered in their methodological training. This training could, however, serve as the link between theory and practice; between pedagogical knowledge and the teaching of subject matter. There is a strong belief that methods courses do not have an impact on the development and reformation of practice, even though they are intended to do so. It has been suggested that pre-service teachers' perceptions of teaching are based strongly on their own experiences of school as a student (Abell 2000), and that such entrenched beliefs can persist throughout teacher education and into teaching service unless they are intentionally addressed (Fajet, Bello, Leftwich, Mesler & Shaver 2005).

Accordingly, methods courses should be given due importance by instructors and should also provide opportunities for student teachers to practice teaching approaches within different activities (Yilmaz-Tuzun 2007). By drawing on these notions, a teaching programme focusing on teacher-facilitated talk was designed.

As the preliminary results of earlier research (Viiri & Saari 2006) have shown, awareness of teacher talk can have an effect on student teacher talk when conducting science lessons. In view of this, the main purpose of the teaching programme on teacher talk was to introduce student teachers to the concept of communicative approach developed by Mortimer and Scott (2003), as well as to introduce other relevant theories concerning discursive and questioning strategies (Chin 2004, 2006, 2007). The aim was that student teachers would become aware of the concept of the communicative approach when planning, carrying out and reflecting on their own physics lessons and, furthermore, to provide a forum where they can examine and challenge their existing teaching beliefs and practices. The teaching practice was carried out in teacher training schools.

One of the key concerns of peer reviews of the teaching programme was the role of the teacher tutor. In reference to this, lessons were conducted under the supervision of the teacher tutor, but as a rule without any interference or support. Furthermore, the author provided the student teachers with guidance and tutoring at a general level, but did not influence the content or execution of the video recorded lessons. Only a basic structure for planning episodes and communications was provided. During the interventions it was realised that when adopting innovative teaching methods support for beginning teachers should be even greater than merely providing information before and feedback after the lessons. The guidance was, however, restricted to providing student teachers with the required knowledge, and the focus was on examining the possible effects of this on lessons and perceptions. More specifically, before the implementation phase student teachers were introduced to the theory behind teacher talk and practised the categorisation of communicative approaches using videos and by observing tutor teachers' lessons. As regards the need for more support, in forthcoming teaching programmes student teachers could also be guided through the planning process with more explicit guidance in relation to content.

The role of the teacher tutors could not be controlled. But, based on my experiences as a physics student teacher and the interview with teacher tutor Mr. James, dialogic teaching and its pedagogical aspects are not explicitly brought up in teacher training school:

> Author: Have you agreed that you will follow sociocultural views here?
> Mr. James: We have not agreed that there would be any theoretical framework. But, when you reflect on the things we do, it would be quite close to that… it can be seen every day in pair work, group work and so on. So, in our subject group we have a lot of actions that could be considered to be sociocultural and collaborative learning by nature.
> Author: That is also how I remember it… Do you bring up different communicative approaches here?

> Mr. James: No. We don't use that expression… It (the concept of communicative approach) is a part of more analytical practices like teachers doing research… we don't bring it up with student teachers in our tutoring, since we consider teacher talk as being very closely connected to one's personality… we try to support more the efforts that come from student teachers themselves.

This is a part of a larger interview with Mr. James (pseudonym used in Article II) addressing the culture of the university teacher training school and the role of the teacher tutors in providing information related to the teaching programme. The excerpt conforms to the findings of Asikainen and Hirvonen (2010), who found that cooperating physics teachers (correspondingly teacher tutors) tend to focus more on daily practices rather than bringing forth the educational theories behind the practices. Nevertheless, at the same time, as the excerpt above indicates, the teacher training school is an environment where socio-constructivist, or even dialogic practices, can be found if they are intentionally sought. However, according to Mr. James, the communicative approach is not discussed in detail in teacher training school. Although external influences cannot be completely discounted, the teaching programme on teacher talk can be considered reasonably independent from its context after all.

4.2 Participants

The study had two main areas of focus: teacher education and classroom realities in the field, and, accordingly, two main participant types: student teachers and in-service teachers. Furthermore, student teachers constituted both science student teachers and primary school student teachers. The study thus focuses on three different subgroups with different backgrounds in addressing the main research questions.

Article I. The in-service part of the study took place during semester 2008–2009. In Finland, all students of the 25 classes participating in the QuIP project were 9th graders. The sample size was 25 teachers (and 380 students with an average age of 15.6 years). The classes were therefore all taught by different teachers from different schools. Finnish subject teachers generally major in physics, chemistry or mathematics. Usually they are required to teach all of these subjects regardless of their minor subjects. Today, to be qualified as a subject teacher, both a master's degree in the main subject and pedagogical studies must be completed. In the Finnish QuIP sample, all teachers were qualified and had a major in either physics (11 teachers), mathematics (11 teachers) or chemistry (3 teachers). The cases indicating a dialogic approach and distinct communication structures were examined further and were called Teacher A and B to preserve anonymity. Both of these selected teachers had majored in physics teaching, although they also teach chemistry and mathematics. Teacher A had seven years' and teacher B fourteen years' experience teaching physics, respectively.

Article II. The voluntary participants consisted of science student teachers whose major subject was physics. The physics student teachers (n=12) conducted the teaching programme alongside their subject teacher training during academic years 2007–2008 (n=6) and 2008–2009 (n=6). Physics student teachers in Finland usually study 3–4 years of physics before conducting a one-year teacher training period. For science student teachers it is also recommended to have some basic studies in minor subjects such as mathematics and/or chemistry.

Article III. During academic year 2009–2010 primary school student teachers (n=28) were introduced to inquiry-based learning, and introduction of the dialogic aspect was integrated into the course by executing the theory and observation parts of the teaching programme. Whereas physics student teachers specialise in physics and minor subjects such as mathematics and/or chemistry, primary school student teachers often complete subject-level courses in science, which have become increasingly common since the introduced inclusion of science in the primary school curriculum. The aim was for primary school student teachers to:

- Become aware of their conceptions about science teaching and science content knowledge
- Learn to carry out project work in collaborative settings
- Strengthen their knowledge of dialogic inquiry-based teaching and content
- Plan a dialogic inquiry-based teaching environment for students

The general aim of the course was for student teachers to shift their focus towards learning processes and dialogic aspects rather than being exclusively concerned about their own subject content knowledge. The course was conducted mainly by the second author of Article III and the dialogic aspect was introduced by the first author.

Article IV. The dialogic inquiry-based teaching course was executed with minor revisions also in the following academic year (2010-2011). This time, the research focus was more on how student teachers implement the model of dialogic inquiry-based teaching in initial teacher practice. The overall group included 20 primary school student teachers. The lessons were planned and executed in subgroups comprising 4–5 students.

4.3 Analytical framework

Although dialogic teaching and related concepts are present overall in the study, each article offers specific approaches to accessing these aspects. There is also overlap between the articles with respect to analytical solutions. For instance, Articles II and III overlap in their interview approach when mapping student teachers' views, and Articles I, II and IV overlap in their use of videos to identify dialogic interactions. Indeed, videos were essential artefacts in Articles I, II and IV, and this aspect is rationalised further in the corresponding papers. The following sections provide a more general description of the data collection and the rationale for the analytical choices.

4.3.1 Data collection

Dialogic teaching in classroom realities

Article I. As introduced earlier, the data of this part of the study was collected within an international video study called Quality of Instruction in Physics (QuIP) (Helaakoski & Viiri 2011; Olszewski 2010). The PISA guidelines for the selection of participants were followed. A total of 25 teachers from central Finland were randomly selected for the QuIP study, which investigated features of pedagogical content and content structure with respect to both teachers and students. Data was collected in various forms for several doctoral research projects (covering, e.g., student pre- and post-testing, teacher's content knowledge, teacher's pedagogical content knowledge). For this study, only the Finnish video data was used to address the research aims introduced earlier. The results of the international part of the study will be examined once the work in each of the key focus areas has been completed.

The collection of video data was carried out in strict accordance with guidelines from previous classroom video studies (Seidel, Prenzel & Kobarg 2005). The equipment consisted of two cameras, four wireless microphones, an audio cube, and a laptop for storing the AV data. An action camera was used to follow the teacher and a still camera to film the students. A microphone was attached to the teacher to ensure that the teacher talk could be isolated when necessary. Other microphones were installed to ensure the students' utterances were recorded effectively. In this study the action camera was mainly used to follow whole-class teaching sessions and, where necessary, microphones were isolated and listened to separately if utterances were not otherwise clearly registered.

Student teacher views and implementation of dialogic teaching

Article II. During the years (2007–2008 & 2008–2009) that the teaching programme was carried out in physics teacher training, data was collected in all phases and in several forms (e.g., written reports and lesson plans, video recorded physics lessons of student teachers, reflective feedback sessions and group interview) for different research purposes, and also to enable student teachers to monitor their progress during the programme. For example, for each physics lesson data was collected in three phases: preactive (planning), interactive (teaching), and postactive (evaluating and reflecting) (Westerman 1991). The videoing followed the same guidelines as in Article I.

Although data was collected from each component of the teaching programme, the purpose was not to use all of the multiple data in the analysis. However, as presented in more detail in Article I, for instance the tracing, analysis and interpreting of dialogic episodes involved examining lessons as well as lesson plans and reflective feedback sessions. Some of the data, such as the small-scale studies, were merely part of the execution of the teaching programme and for monitoring purposes, yet they offered some additional information on student teachers' views about teacher talk.

Article III. In this article, the data consists of three different inquiries from primary school student teachers: pre-conceptions (n=28), mid-interview (n=6), and post-interview (n=6). Whereas pre-conceptions were mapped for all participants, the mid- and post-interviews were collected from a single group of six student teachers who were selected for more longitudinal whole-course examination. The data collection approach was different in each phase and the varying data types included essays, transcribed interviews and semi-structured oral interviews.

Article IV. The video data was collected in a similar way as in Articles I and II. However, as the teaching and inquiries were planned and carried out by groups of 4–5 student teachers, the location of the teacher microphone depended on the student teachers' activities and locations.

Interviews were an essential means of gathering information on student teachers' conceptions in Articles II and III. In Article II, interviews were implemented in different ways in different phases of the teaching programme. In the beginning, pre-conceptions were addressed in collective settings during introductory lessons. After the planned and executed lessons, a video-supported *stimulated recall interview* technique (O'Brien 1993) was applied in individual reflective feedback sessions. Finally, group interviews were conducted at the end of the programme when experiences and conceptions of the dialogic approach were shared. Generally, in all of the interviews, in order to avoid undue concern among the student teachers regarding their teacher behaviour, the interviews followed a more informal semi-structured interview format as opposed to being formal and strictly directed (Orland-Barak & Yinon 2007). However, some preparations were made and some (especially dialogic) episodes were pre-selected to be commented on by the student teachers in order to access their decision making and perceptions about the planning and implementation of the dialogic approach.

In Article III, individual interviews were conducted in three phases (pre-mid-post) and in different forms including questionnaires, essays and oral interviews. As previously mentioned, openness was central to the interviews.

Group interview was applied in Article II. This specific form of interview was chosen so that student teachers could refresh their memory about the teaching programme as a whole and build on the comments of their peers. When necessary, the facilitator posed, for example, follow-up, probing, or specifying questions (Kvale 1996) in order to seek more or an extension of ideas and also to maintain the flow of the discussions. The possibility to probe interviewees further is one of the key strengths of the interview approach, especially in group discussions (Eybe & Schmidt 2004). Although openness can serve to reveal authentic and unexpected thinking, further elaboration may be required in order go deeper and reveal emerging notions. In other words, in an open-ended interview the respondent can be asked to elaborate his or her own insights into certain occurrences and these elaborations can be used as the basis for further inquiry (Yin 1994). In addition, the facilitator elaborated upon the responses by reflecting on his own similar/differing experiences in order to maintain the flow and continuity of discussions whenever, and only if, necessary.

Despite their advantages, interviews entail a number of pitfalls in terms of validity. Although use of leading questions may be necessary for purposes of clarification, steering the interviewee towards a ”correct” or propitious response can be a severe drawback. As presented within our conceptual framework, the same characteristics within classroom discussions make interactions consisting of IRFRF chains seem less authentic. Briefly, renegotiation should be avoided to maintain the trustworthiness, validity and objectivity of inquiry. As Kvale (1996) states, interviewer experience and skill are key to achieving high quality and reliable interviews. Reflecting on this, the data collectors in the present study are considered to be aware of the theory and practices of the dialogic approach and of different questioning approaches, which provided an optimal background for conducting open-ended interviews within this study. More detailed descriptions of the interview execution are presented in Articles II and III.

4.3.2 Data analysis

As mentioned in the previous sections, a number of methodological innovations for examining classroom interaction have been developed in recent years. These solutions, while being applicable also to science classrooms, vary in terms of their focus. In general, methods of analysis of classroom interaction are often highly qualitative and flexible, which can be both detrimental and beneficial to research. On the positive side, these characteristics enable the researcher to address their research questions using the most suitable analytical tool for their purposes. This kind of practical approach to data analysis could be considered to mirror the pragmatist view (Creswell & Plano Clark 2007). Pragmatism was also present in this study in terms of providing accessible data for teachers and teacher educators to be applied in their teaching and teacher education.

Originating from the pragmatic approach, the mixed method was considered in the design phase of the study. However, as the hypothesis predicted, the scarcity of dialogic interactions directed the work towards a more qualitative approach. Details of the analytical approaches used are presented in the following subchapters. By way of a general overview, however, the Atlas.ti software was used in the analysis, which is designed for qualitative analysis, but can also be used for quantitative procedures such as coding events. Since the data analysis approaches used overlap between articles, this dissertation provides a general background of the analytical approaches used rather than giving article-specific descriptions (these are provided in the articles and are also summarised Table 1). In general, the analysis includes the following main methods: thematic analysis of the interviews, (cross-) case analysis, and analysis of classroom communications including visual presentation and analysis of communication graphs.

Thematic analysis was the main approach used to analyse the interview data. The method offers a flexible means of analysing and illustrating a large set of interview data. It is on this very flexibility that criticism of the approach is generally based. However, as Braun and Clarke (2006) emphasise, the key here is in reporting how this flexibility is used. Briefly, thematic analysis identifies, analyses and reports themes (patterns) within data, and a theme captures something relevant about the data in relation to the research question. The process of thematic analysis also includes defining what counts as a theme, which, according to Braun and Clarke (2006), is up to the researcher to decide.

There are two primary ways to identify themes from a data set: inductively (data-driven) or deductively (theoretically). In inductive analysis the researcher is not trying to fit the data into a pre-existing coding frame, rather the analysis is data-driven. On the contrary, deductive analysis is more driven by the researcher's theoretical or analytic interest in the area. The deductive approach is considered to be more detailed with respect to certain aspects of the data, whereas inductive analysis gives a broader overall description of the data. Another key consideration in thematic analysis is the level of analysis to be made. The explicit (semantic) level remains strictly within what is seen in the interview data and goes no further. The latent level, however, is where interpretations are made, where instead of merely describing the data the analysis goes beyond the surface and examines the underlying ideas, assumptions and conceptualisations (Braun & Clarke 2006). In this study, inductive analysis at the latent level was applied to the interview data. The analysis followed the principles defined by Braun and Clarke (2006).

The *analysis of classroom communications* was based mainly on videos rather than on careful scrutiny of transcribed talk. In other words, linguistic marks were not included in the excerpts of discourses in order to improve the readability for the common reader. Gestures, intonations and additional contextual cues were derived from the videos and necessary information was provided in transcripts. The theoretical background of the video analysis was the framework developed by Mortimer and Scott (2003). Besides considering the actual communicative approaches, the relation to teaching purposes and content was also taken into account. That is, in order to establish trustworthy interpretations of communications and specific communicative approaches, other relevant factors were also weighted.

With regard to *quantitative versus qualitative* positioning, in this study qualitative approaches were mostly applied, although in Article I quantitative procedures were initially conducted to some extent in order to trace indicating dialogic interactions from the videos. In this sense a mixed-method design was applied (Creswell & Plano Clark 2007), firstly to quantitatively seek dialogic interactions, and secondly to examine the identified dialogic interactions more deeply with more qualitative methods. Whereas here an introduction to the background of the analysis is provided, a more detailed description of the analytic steps within the video analysis can be found in the corresponding articles (I, II & IV).

Depending on the research purposes and the amount of data analysed, researchers may decide whether to apply a quantitative or qualitative approach, or both, to reach their aims. Nevertheless, ultimately, it is the research questions and the theories behind them that determine the approach to be used (Derry et al. 2010). Quantitative analysis allows numerical outputs and correlations, for instance. Talk types could, for example, be coded according to pre-determined categories and statistical variables and then correlated with each other. An example of this kind of analysis is CLASS (classroom assessment scoring system), developed by Pianta et al. (2008), which is widely used in studies by the present authors' colleagues (e.g., Pakarinen, Lerkkanen, Poikkeus, Kiuru, Siekkinen, Rasku-Puttonen & Nurmi 2010). Although these systems allow trustworthy and reliable investigation of large sets of data, Mercer (2004), however, warns that in systematic observation studies analysts are vulnerable to losing sensitivity to what is actually taking place in classroom interactions.

Whereas in quantitative analysis the actual talk can be lost behind numbers and statistics, in qualitative analysis collective thinking and joint construction of knowledge is carried through the analysis (Mercer 2004; Mercer, Littleton & Wegerif 2004). Transcribed talk and interpretations provide readers with a more complete picture than numerical findings tend to do. This kind of analysis is, however, very time consuming, which leads us back to the issue of the amount of data to be analysed and displayed. Furthermore, critics of qualitative methods speak up for the power of quantitative studies to support generalizability. One of the biggest weaknesses of quantitative methods is that talk is generally not seen as continuously developing over time. The temporal aspect of classroom discourse should thus be present in the analysis (Mercer 2008) in order to make sense of what has been and what is to be said. This aspect has been given increasing, albeit not yet sufficient, attention in educational research (Lemke 2000; Ludvigsen, Ingvill, Rasmussen, Krange, Moen & Middleton 2010; Scott, Mortimer & Aguiar 2006).

Temporality was given explicit attention in this study in examining how classroom communications progress over time and constitute specific communication structures (particularly Article I). Such a cumulative communication structure reveals whether and how learners' pre-conceptions and efforts were taken into account when moving towards more scientific definitions. More theoretically, it reveals the way different types of actions and communications are connected and how they support each other. In this study, to capture the temporal nature of talk, communication graphs of teaching sequences were created in order to visualise characteristic features of teacher communication.

Communication graphs were considered an innovative approach to addressing the temporal and dynamic aspects of classroom communication, to which the above-mentioned communication structures also closely relate. The current body of research contributing to representational visualization of communications and interactions taking place in classrooms remains limited (Roth 1997; Viiri & Saari 2006), and the analytical solutions presented in the literature, to which the present study also contributes the innovative new methodological approach described here, are therefore still novel. Communication graphs can be understood firstly as visualizations of analysed communications. Examination of the graphs could, however, also be an essential part of cross-case analysis when defining teacher-dependent and repeating structures, or simply when concluding the general nature of the communications. For instance, the nature of communication could be crudely classified as being simply authoritative or dialogic or, similarly, interactive or non-interactive within the overall illustrated teaching sequence.

The creation and visual appearance of the communication graphs (articles I, II & IV) were dependent on the unit of analysis, and the unit definition was dependent on the specific research purpose. Classroom communication can either be coded in turns, in which case the unit of analysis consists of sentences or time intervals, or the analysis can begin by selecting episodes consisting of teacher-student exchanges. The first option can be understood as micro-level analysis, and the second as meso-level analysis of classroom discourse. Accordingly, the macro level could include analysis and comparison of whole teaching sequences or several teaching sequences (Tiberghien & Malkoun 2008). Klette (2009) has argued that different levels of analysis and representations of data should be conducted in order to avoid misinterpretations. Indeed, in Klette's (2009) study the use of different layers of analysis in interpreting actions in the classroom provided complementary results and strengthened the final interpretations. This aspect is illuminated further in Article I.

In Figure 6, three communication graphs are illustrated in order to present some examples of and basic differences between the graphs used in the study. In all of the graphs the horizontal axis represents time and the vertical axis different communicative approaches. Individual descriptions of the example graphs are presented below:

- In *graph A*, from Article II, a micro-scale and temporal analysis was applied. Indicators of specific communicative approaches were coded in 20s intervals. Therefore 1 minute could include several communicative approaches. Abbreviation O stands for other actions, such as general announcements from the central speaker.
- In *graph B*, from Article I, a meso-scale approach was selected to create an overview of communication during a 90-minute teaching sequence. Episodes were first selected based on activity type, topic and changes in communication. After this, the dominating communicative approach was selected for each episode. In addition

to the original classification of communicative approaches, combinations of interactive/non-interactive (I & NI) categories were derived to increase the visual (vertical) scale of communication.

- In *graph C*, from Article IV, a meso-scale approach was applied similarly to graph B. However, in this case an inquiry phase is also included above the communicative approaches. The main reason for this was to be able to scrutinise whether structures resembling dialogic inquiry-based teaching (opening up-inquiry-closing down) could be identified.

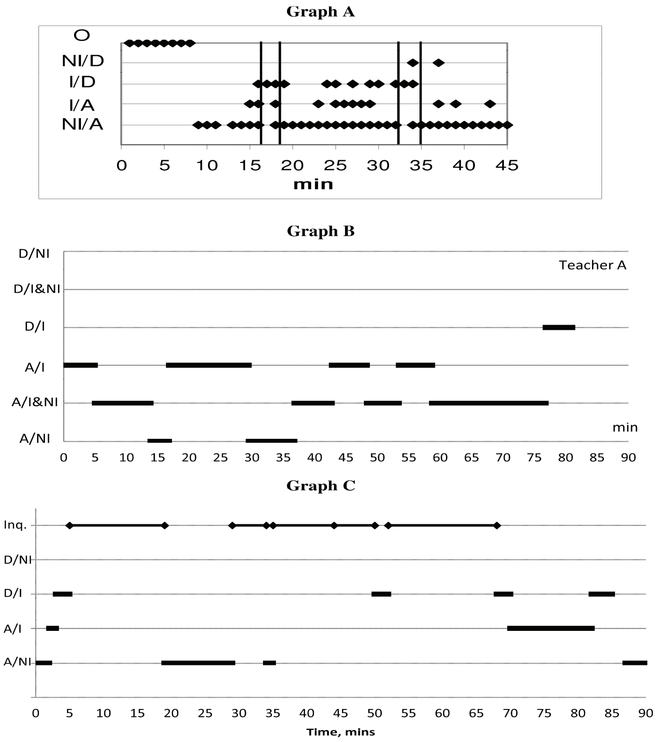

FIGURE 6 Examples of communication graphs (for example, the communicative approaches and inquiry phase in Graph C took place in the following order: 1. Authoritative/Non-Interactive, 2. Authoritative/Interactive, 3. Dialogic/Interactive, 4. Inquiry phase)

The major difference between the graphs is evident from graph A, where the dialogic turns dominant within an episode were confirmed afterwards. This involved scrutinising parts of the lesson in which a dialogic approach was evident, identifying the types of activity and teaching purpose and then, finally, judging whether any episodes were dialogic. These confirmed dialogic episodes were then marked explicitly with vertical lines on the graph. In contrast, in graphs B and C the procedure began with defining the episodes prior to selecting the dominating communicative approaches. Whereas in the first case all of the turns indicating a dialogic approach, that is, possible attempts to initiate dialogic episodes, can be detected, in the other cases these attempts are hidden behind interpretations of the dominating communicative approach. It is left, therefore, to the researcher(s) to decide whether this information is essential to the research. The communication graphs can be considered as initial, innovative attempts to visually address the temporal structures of classroom communication, such as cumulation and dialogic inquiry-based teaching. In this respect, the meso-scale interpretations do provide essential information. As a limitation to be acknowledged, however, the communication graph alone does not provide information about the actual quality of the communications. Rather, it is a surface-level visualisation that can be used, for example, to indicate whether the above-mentioned structures occur within the teaching sequence.

Cross-case analyses were conducted in order to identify similarities and differences between cases and the overall results were summarised. In this way, the findings were discussed at both the individual and collective level. Presentation of the data can be considered a crucial part of qualitative data analysis (Yin 1994; Miles & Huberman 1994). For instance, matrices of cases and variables are often preferred in illustrations. Furthermore, as previously highlighted, communication graphs offer a unique means of parallel examination of teacher-specific features of communication and, especially, structures comprising different communicative approaches. Although cross-case analysis can provide a chain of evidence supporting generalizability, in this study attention is paid to exceptions that shed light on uncommon dialogic interactions in science classrooms.

All *transcriptions and translations* of the first article were composed by the author. In the second and third articles additional translation and transcription assistance was provided by assistants working and studying in the department of teacher education. All translations were, however, composed initially by the author. The completed translations were discussed with a native English colleague working in a similar field of research in order to maintain the authenticity of the Finnish-English translations (Nikander 2008). Furthermore, any translations used in the analysis of the data were carefully scrutinised by several researchers in order to establish trustworthy and objective interpretations. As video data was used to interpret the majority of classroom communications, the conventional need to include detailed symbols alongside the transcriptions was considered redundant. Nevertheless, it was necessary and important to carefully transcribe key excerpts. A selection of these excerpts are included in the results section and in the exemplary communications discussed below.

Overview of the data analysis of the four articles

Table 1 summarises the types of data analysis used in the different articles. Whereas all of the articles were qualitative, based on the background of Article I the study can be considered to include quantitative procedures, such as video coding of events. The analysis of Article I was initially planned to be quantitative but, as observed already during the data collection phase, the expected absence of dialogic interactions guided the analysis in a qualitative direction.

Video analysis was conducted in Articles I, II and IV in order to trace and examine communicative approaches. Researcher triangulation (Cohen, Manion & Morrison 2007) played a crucial role in ensuring trustworthy and valid analyses. For instance, in Article II parts of the interval-based video coding were conducted in parallel by two independent coders. The Cohen's Kappa value of 0.788 ($p<0.001$) indicates the reliability of the video analysis results. In Article II the purposefulness of dialogic interactions were also weighted and verified by scrutinising different forms of data (data triangulation). In Articles I and IV the interpretations of classroom communications required more informal and complex consideration of agreement issues than simple inter-rater measurements. This was, firstly, because the examination of interactions was not time interval-based, and, secondly, because the temporal consideration itself could be considered to increase the trustworthiness of the interpretations. Researcher triangulation was applied also in Article III in order to establish the required objectivity of interview analysis.

Cross-case analysis took place in all of the articles. In general, cross-case illustrations were an essential part of the analysis when providing insights into the differences and similarities between cases.

TABLE 1 Types of data analysis (X=included, (X)=included as supplementary, -=not included)

Analytical method	Article I	Article II	Article III	Article IV
Qualitative	X	X	X	X
Quantitative	(X)	-	-	-
Video analysis	X	X	-	X
- Communication graphs	X	X	-	X
Interviews	-	X	X	-
- Thematic analysis	-	X	X	-
Pre-(mid)-post analysis	-	(X)	X	-
Cross-case	X	X	X	X
Researcher triangulation	X	X	X	X
Data triangulation	-	X	(X)	(X)

5 RESULTS

This section presents the results in parallel with the main research aims. An overview of the key findings of the articles is presented, along with a summary of findings in Table 2. Detailed descriptions of the findings are presented in the corresponding articles and, thus, overall evaluation of the validity of the observations and interpretations should be done on the basis of the articles.

5.1 Dialogic interaction in the science classroom: a case example

Dialogic interactions were traced from the entire data set of 25 Finnish science teachers by initially searching for any teacher-orchestrated interactions that might initiate dialogic interaction. After careful scrutiny of the videos and transcriptions, three dialogic episodes were confirmed to have taken place among three different teachers. As might have been expected, dialogic interaction seems to be very infrequently facilitated in Finnish classrooms. Once all possible initiations and indicators of dialogic discussion were traced and coded from the videos, the initial results revealed that in whole-class teaching sessions only three out of 60 open questions fulfilled the criteria for a dialogic approach at the episode level. These numerical results were presented at the ESERA 2011 conference in Lyon (Lehesvuori, Viiri, Rasku-Puttonen & Helaakoski 2011). Based on the feedback received, the focus of interest was then turned to the case example that resonated most with the concept of meaningful learning of science.

After examining the occurrence of dialogic episodes in 90-minute teaching sequences at different scales of classroom communication (micro, meso and macro), only one teacher was found to fulfil the criteria for fostering meaningful learning of science through a dialogic approach. As emphasised earlier, according to Scott and Ametller (2007), in particular, meaningful learning of science should include both dialogic and authoritative approaches in order to give students opportunities to express their own ideas before drawing on more scientific explanations. The exemplary teacher (Teacher B) provided space for observations and sharing of observations without evaluating student responses. Furthermore, the teacher elaborated the students' ideas before presenting the science view through teacher demonstration and instruction.

Whereas, compared to the example case, the other teacher example (Teacher A) balanced between non-interactive and interactive authoritative approaches, the exemplary case teacher managed to open up space for dialogic discussions before narrowing towards more authoritative approaches. This latter exemplary approach can be considered to be in line with a *cumulative communication structure* in which students' contributions are viewed being as part of the process of doing science. The approach also reflects the principles of genuine scientific inquiry (Minner, Levy & Century 2010). During this process students had an opportunity to explore, explain and weigh their ideas against scientific definitions. Not only did the teacher foster a dialogic approach, he also established an advantageous rhythm of talk (Leach & Scott 2002; Viiri & Saari 2006) consisting of varying communicative and pedagogical approaches.

The temporal consideration of classroom talk was central to the examination of communication structures. In this part of the study, the development and progress of communications over time were thoroughly examined by means of communication graphs as well as scrutiny of transcribed interactions of key episodes. In doing so, different analytical layers were considered before finally confirming whether a cumulative structure was present. The methodological implications of this aspect are addressed below after the general discussion.

5.2 Student teacher views of dialogic teaching

Student teacher views regarding dialogic teaching were mapped during both subject teacher training and primary school teacher training. Both of these groups were asked about their conceptions of dialogic teaching, but in slightly different ways. Whereas in Article II this aspect was only a part of the overall study, in Article III it was the main goal. The results of the third article support those of Article II, especially with regard to student teachers' increased awareness about different aspects of teacher talk. Primary school student teachers' preconceptions were found to focus on traditional ways of science teaching without acknowledgment of the dialogic approach, such as outdoor education, lab work and practicality in general. Some elements, such as taking account of students' prior conceptions, were present in their conceptions, but further awareness of communicational options and dialogic teaching did not emerge in the beginning.

In Article III, in addition to mapping 28 primary school student teachers' prior views regarding "good science teaching", six cases were examined further in terms of learning trajectories. All of the trajectories revealed increased awareness about (dialogic) interaction, though at different levels. According to the awareness criteria used, the lowest level represented the student teacher having no recognition of the principles of dialogic teaching or of varying communication styles in general. At the highest level, the student teacher would have adopted the idea of different levels of inquiry and the role of different communicative approaches constituting the opening up and closing down phases of inquiry, and principles of dialogic teaching would be reflected in their views. Four of the six cases of primary school student teachers were considered to achieve a sufficient level of dialogic teaching awareness according to our dialogic inquiry-based teaching criteria to be able to plan and execute dialogic inquiries in practice. The Anniina case, for example, showed the highest development in awareness of dialogic inquiry-based teaching (Figure 7).

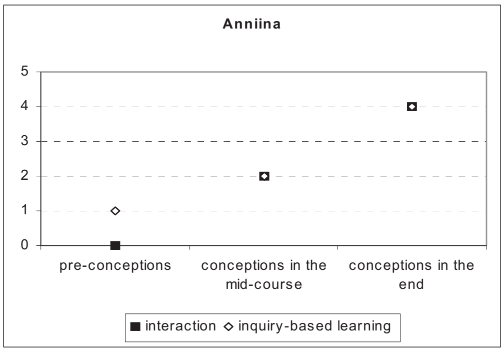

FIGURE 7 Learning trajectory of Anniina

By the end of the course, Anniina showed awareness of principles of dialogic teaching and communicative approaches and their role within different phases of inquiry. However, as in the majority of the cases, the authoritative approach was not given sufficient recognition as being a crucial mediator for connecting everyday views with scientific views. Rather, teaching was often seen as black or white: authoritative or dialogic.

The group interviews, which were held at the end of the teaching programme presented in Article II, support the above findings regarding increased awareness of the dialogic aspect. In addition to mentioning increased awareness and the positive influence of the dialogic approach on science teaching, sophisticated comments about the challenges associated with dialogic implementation also emerged during reflections and group interviews. The main potential challenges to implementing a dialogic approach mentioned were related to insufficient content knowledge, discipline issues and the use of time. More infrequent, yet higher levels of reflection during group interviews addressed how insufficient pedagogical content knowledge (e.g., knowledge about misconceptions) could lead to extended dialogues not taking place:

> I just discussed this in that small scale study, because at no phase of the pre-service period are you told what kind of prior knowledge pupils have. And you are also in trouble yourself when you try to discuss when necessary… And there might be questions you cannot answer… And for sure, some of those questions come up frequently every

> year… So if you have taught one or two times you could know how to answer. I was wondering if I would have felt the dialogic discourse easier, if I'd had some material or background reading where there were dialogues that possibly would emerge. [Joanna, physic student teacher 08-09]

In her comment, Joanna refers to knowledge of student pre-conceptions and how this could help the teacher in promoting dialogic interactions. This kind of knowledge is related to pedagogical content knowledge, and a student teacher acknowledging its importance to classroom communication indicates significant development towards dialogic reformation.

Joanna was also one of the student teachers who succeeded in implementing a dialogic approach during her video recorded lessons. As regards student teachers' views in general by the end of the course, it can be concluded that although they see the dialogic aspect as an essential part of classroom communication, they are still concerned about the actual implementation of dialogic pedagogy in the reality of the classroom due to the challenges identified. However, as the further results demonstrate, the student teachers were, to varying extents, able to include this aspect in their initial teaching practice.

5.3 Student teacher implementation of dialogic teaching

Despite the student physics teachers' apparent awareness of the challenges of dialogic pedagogy, the results show that they were also able to challenge the traditional authoritative forms of teaching by including a dialogic communicative approach in their lesson plans, implementation and reflections. Cross-case analysis and communication graphs of the student teachers revealed that the majority implemented dialogic approaches during their video-recorded lessons. Careful scrutiny of the lessons, lesson plans and the reflective feedback session revealed that 7 out of 10 physics student teachers intentionally applied a dialogic approach in their teaching during the two video recorded lessons. As said, however, at the same time the student teachers recognised several key challenges associated with implementation of a dialogic approach. These were related to use of time, discipline and insufficient content knowledge.

Whereas at a general level the student teachers acknowledged the teaching programme as providing tools for enriching communication in the science classroom, the graphs of Paul and David's lessons (see Article II) demonstrate more specifically how the lesson structure can be planned to support dialogic implementation. Paul, who was familiarised with dialogic teaching, planned and implemented a dialogic approach in different parts of the lesson (see graph A, Figure 6), whereas David's lesson followed a typical lecturing format. David was informed about dialogic teaching during the reflections after the lesson. Whereas Paul had adopted a dialogic approach to lesson planning and teaching, David's initial lesson plans and reflections seemed to focus merely on the correctness of the scientific content.

As the exemplary cases of Paul and David in Article II illustrate, Paul deliberately applied a dialogic approach in different parts of the lesson, whereas David used a dialogic approach only in the introduction phase of the lesson. Although the episodes Paul applied were of a different quality in terms of educationally purposeful science learning (Lehesvuori & Viiri 2008), his lesson was executed closely in line with his lesson plan, with communicative approaches included. On the basis of this notion, and Paul's comments emerging during the reflective feedback session, it may be argued that due to his planning of dialogic episodes, Paul's execution of a dialogic approach was more frequent and purposeful than would have been the case without these preparations. Conversely, David's lesson plans and reflective feedback session confirmed that, despite being mid-way through his teacher training, he was not able to specify the nature of the communications he had applied.

Within the study conducted in Article IV, the student teachers planned and executed dialogic inquiry-based teaching in groups. The study was a continuation of the study in Article III, this time the focus being on student teacher implementation. The communication graphs indicate that the groups followed the framework for inquiry to varying degrees. Whereas in one group the opening up, inquiry, and closing down phases were clearly present (see graph C, Figure 6), one group's teaching sequence resembled traditional lecture-based teaching interrupted by short experiments. The other two groups followed the framework for dialogic inquiry-based teaching partially. To conclude, with the exception of one group, the student teachers were to varying extents able to challenge traditional forms of teaching and to expand concise pre-defined tasks and experiments towards authentic inquiry in which students were given opportunities to elaborate their views with their peers.

5.4 Summary of the main results

Science classroom teaching continues to be dominated by authoritative approaches and, where occurring, the use of open questions is failing to serve its intended purpose of engaging students in deeper levels of discussion. Whereas a socio-constructivist approach may be apparent, for instance, in forms of experimentation, teacher-led discussions are not taking advantage of students' experiences and observations, rather students are being rigidly steered in pre-defined directions. As the exemplary case, however, reveals, dialogic pedagogy can be implemented in the reality of the classroom in a manner that fosters more dialogic and meaningful learning of science.

Overall, the results of the teacher education part of the study provide insights on how student teachers adopt dialogic teaching into their views and practices. At the same time, the results suggest that while dialogic pedagogy is attainable for novices, the prevailing cultural reality in the field is clearly not favourable towards dialogic approaches. This was also acknowledged by the student teachers themselves in terms of the challenges regarding time use, discipline and insufficient content knowledge. These issues are reflected on further in the following section in which the discussion is expanded to cover the basic grounds for professional development. First, a brief summary of the main findings is presented in Table 2 below.

TABLE 2 Summary of research questions and main findings[4]

	Main research questions	Main findings
1)	How do dialogic interactions manifest in the science classroom?	• Temporal examination of the selected teachers' teaching sequences revealed different communicative natures when covering the same content (Article I) • Based on communication graph analysis, few dialogic episodes were of different quality: only 1 dialogic episode was confirmed to meet the criteria for building a meaningful and cumulative communication structure (Article I)
2)	How do student teachers adopt dialogic teaching into their views about science teaching?	• Dialogicality was not sufficiently present in the pre-conceptions of student teachers (Articles II & III) • Science student teachers acknowledged the positive features dialogic teaching brings (Article II) • At the same time, science student teachers acknowledged the challenges dialogic teaching might bring, especially in service (Article II) • Primary student teachers' prior views of science teaching rely on very traditional teaching approaches: e.g., outdoor education and experimentation (Article III) • 4 out of 6 cases of primary student teachers indicated increased awareness of dialogic inquiry-based teaching. All cases showed increased awareness of the dialogic aspect (Article III)
3)	How do student teachers implement dialogic teaching during initial teacher education?	• Student science teachers are capable of considering the dialogic approach both in theory and practice during initial teacher education (Article II) • 4 primary student teacher groups applied dialogic inquiry-based teaching principles to varying degrees in initial practice: for instance, whereas one group's communication graph indicated clear opening and closing phases, another group's communications resembled mostly authoritative and traditional approaches (Article IV)

[4] Detailed results are presented in the corresponding articles

6 DISCUSSION

In this section, the main research questions and related findings are discussed. As this project covers different contexts of teacher practice and professional development in the field of dialogic teaching, these will be first discussed in separate chapters. The in-service context and current status of classroom communications in science classes is also discussed by reflecting on the results of this study and previous research. The teacher education context is also addressed in terms of how student teachers could adopt dialogic teaching into their views and practices during their initial practice. Final comparisons and future suggestions are then provided by addressing the grounds for sustainable reformation towards more dialogic teaching.

6.1 Dialogic teaching in the science classroom

Based on previous observation studies and the general findings of the present study, it seems that the authoritative classroom is clearly the prevailing norm. This urgently calls for dialogic interventions to be executed already during initial teacher education. As expected, dialogic interactions seem to be largely absent from the Finnish science classroom. Similar findings have been reported, for example, for UK science classes (Mercer, Dawes & Staarman 2009). Not only the absence, but also the deficient quality of the few dialogic interactions provide sufficient rationale for integrating this aspect explicitly into teacher education programmes and courses. The dialogic episodes identified in this study, while lacking in quantity, give hope that dialogic interaction is attainable in science classrooms despite the prevailing authoritative culture.

The reasons for the existing lack of dialogic interaction seem to be multifaceted. As has been discussed, teacher control over correctness is often not recognised as a problem due to the traditionally authoritative nature of school science. This, however, should be acknowledged as a problem, as the teaching approaches applied, such as lecturing, teacher demonstrations and recipe-following experiments, fall consistently short of the general guidelines set for more inquiry-based science teaching in comprehensive schools (FNBE 2005; NRC 2000).

Although authoritativeness seems to be embedded in classroom realities, there is some evidence that the integration of inquiry approaches into curricula has had an influence on the communicational stance of teachers (Wells & Arauz 2006). However, although in Wells and Arauz's (2006) study the dialogic aspect was shown to be more frequently present in teaching, authoritative approaches were still found to dominate classroom communication. This signals the need for more specific and explicit accentuation of the social aspects of classroom communication (Oliveira 2009, 2010a).

Resonating with the previous notions, the crude assumption that teachers simply teach as they were taught (Abell 2000) leads to the hypothesis that today's teachers are not fully aware of the dialogic option and what authentic dialogism truly means in science classrooms, that is, the inclusion of different voices (Bakhtin 1986) as being an essential part of meaningful learning of science (Scott & Ametller 2007); and that teachers do not acknowledge the dialogic aspect as being part of good science teaching due to a lack of dialogic role models. Indeed, the frequent use of short IRE exchanges, in which the teacher poses closed questions and evaluates (E) student responses, has even been acclaimed as a desirable model for effective teaching (Mercer, Dawes & Staarman 2009). Undoubtedly, this is the case if the teacher's specific aim is to monitor and check students' knowledge and learning of technical and memorised knowledge. Simple questions are also an effective way of keeping students attuned to the tasks at hand, this way enabling control over the use of time. However, in light of our understanding of the role of language in supporting more in-depth and meaningful learning, the only way to access student reasoning and understanding is to engage them in expressing what and how they really think. This is facilitated most effectively through strategic use of open questions (Chin 2007; Ruiz-Primo 2010; She & Fisher 2002) followed by supportive elaboration of emerging ideas by the teacher. In addition, an arguably essential factor for any learning is the frequent use of open questions, which has been linked to students' positive attitudes towards learning science (She & Fisher 2002).

Due to the absence of dialogic engagement in classroom realities, in this study the examination of in-service teachers was targeted more towards example cases. The dynamic aspect of talk and *how talk develops over time* was especially brought into focus. This was realised via communication graphs from which the overall *communicative nature* and distinct *communication structures* were identified. These concepts are related to the temporal properties of teacher talk. Some of these aspects are addressed in the existing, yet limited, literature (Alexander 2001; Littleton & Kerawalla 2012; Nystrand et al. 2003). In particular, Alexander (2001) has introduced the idea of different scales and layers of communication conveying different meanings. In the present study, these aspects were directly addressed by considering entities of communication, including distinct communication structures as well as more micro-scale moment-by-moment interactions.

Whereas in previous studies communications are represented in the form of lists and tables (e.g. Molinari & Mameli 2010; Nassaji & Wells 2000), in this study also the horizontal scale was given consideration. Visual illustration of communications offers advantages compared to statistical displays addressing a more historical aspect. Firstly, in addition to historical aspects, the dynamic visual aspect illustrates how talk develops over time. Secondly, talk can be viewed parallel to pedagogical intent and enables time to be seen as manageable, which is a valuable feature for novices when reflecting on their practice. Indeed, the latter aspect was one of the main reasons why temporality became a major interest within this study also within the context of teacher education. In working with the student teachers, this concept of time as a manageable resource became central when planning and applying different communications during initial practice.

6.2 Dialogic teaching in teacher education

As a promising enhancement to the authoritative classroom, the findings of the teacher education part of the study give hope that student teachers are able to challenge traditional authoritative forms of teaching in both theory and practice. As student teacher awareness of dialogic teaching increased, so, too, did their application of a dialogic approach within their initial teaching practice. Although the execution of a dialogic approach varied in degree, and in a few cases did not take place at all, the majority acknowledged the positive features that a dialogic approach can bring to the lesson. These features included, for example, the positive influence on the classroom climate enabling extended dialogues to emerge. Moreover, recognising the different roles of the communicative approaches was considered important.

Indeed, besides introducing student teachers to the alternative dialogic approach to science teaching, it was not forgotten that the authoritative approach also has its place in meaningful learning of science (Scott & Ametller 2007). Moreover, it was emphasised that no single communicative approach alone is sufficient to meet the need for in-depth learning. The preliminary results of one study suggest that a mix of authoritative and dialogic forms of teacher talk may be more beneficial for learning outcomes than talk consisting of only one or the other (Furtak & Shavelson 2009). Similarly, it has been proposed that the quality of teaching depends on the strategic use of a varying set of approaches at different stages of the lesson or series of lessons (Mortimer & Scott 2003). Reflecting on the dynamics of talk and time as manageable, it seems that the purposeful planning of communicative approaches had an enriching effect on student teacher initial practice.

Although the degree of success in applying dialogic approaches was varied, more dialogic interaction was nevertheless evident in the student teachers' classroom practice than is generally observed in the field. Nevertheless, worryingly, despite the student teachers' increased awareness of dialogic approaches, they still saw science teaching as either authoritative or dialogic rather than a combination of these two key aspects. More positively, the communication graphs revealed examples of successful teaching sequences with both aspects subsumed in authentic phases of inquiry (e.g., graph C, Figure 6). The varying rate of success is, however, cause for concern.

The major challenges of dialogic implementation brought up by the student teachers were related to questions of discipline, time use and insufficient content knowledge. The discipline and time aspects could hinder teachers in opening up space for discussion as pre-determined lesson goals are often set by the teacher and by curricular requirements (see Scott, Mortimer & Aguiar 2006). It has also been discussed that insufficient content knowledge causes aversion towards open discussion (Childs & McNicholl 2007), which was an issue also present in student teacher comments in the present study. Furthermore, this is not only about the extent to which a more knowledgeable teacher might be able to pose subject-relevant questions (Newton & Newton 2001), but rather how the teacher might react to and elaborate emerging dialogues. As phrased by one physics student teacher:

> "You are also in trouble yourself when you try to discuss when necessary … There might be a question you cannot answer…. I was wondering if I would have felt the dialogic discourse easier, if I'd had some material or background reading where there were dialogues that possibly would emerge" [Joanna, physics student teacher 2008-2009].

These remarks emerged during a group interview conducted at the end of the teaching programme. In addition to highlighting how worried physics student teachers can be about their content knowledge, Joanna was also concerned about how to manage open discussions. Her view suggests that authoritativeness might eliminate, or at least offer a shield against, student initiations that could reveal insufficiency in the teacher's knowledge or threaten the pre-defined agenda and contents of the lesson, on which the teacher is firmly reliant. One can only wonder at the level of concern among primary school student teachers, and even in-service class teachers, over content correctness when teaching science. Within the dialogic aspect, however, teaching should not only be about learning content, but rather about students and teacher alike improving their social and communication skills. Indeed, reflecting on the background theory, teachers and students who are able to communicate within the IDZ are in a position to adopt essential communication strategies for meaningful learning of science, which is possible only when the dialogic aspect is present. In the next chapter, the above concerns are addressed through discussion of some of the acknowledged challenges along the way towards dialogic reform.

6.3 Are novices able to challenge the authoritative status of the classroom?

This section draws together all of the articles included in this dissertation. Whereas Articles II-IV bring to light the possibility of student teacher dialogic reformation, one of the general findings revealed in Article I is that authoritative approaches are still deeply ingrained in science classroom realities. Although the student teachers reported increased awareness of dialogic pedagogy, as evidenced during their practical teacher training, there is still a fear of regression when starting in service.

As the literature presented in this dissertation illustrates, the definitions of classroom interactions present in the literature can be understood in varying ways. Accordingly, it is not surprising that prospective teachers feel that educational courses prepare them inadequately for the in-service demands of the classroom (Stuart & Thurlow 2000). It is therefore important that courses should provide student teachers with a repertoire of alternative, yet explicit, approaches to teaching as well as alternative methods for analysing and evaluating their teaching. However, these courses should not attempt to model complex processes, such as teachers reflecting on their own practice (Schön 1983), rather they should provide explicit ways to evaluate specific aspects of teaching and learning. Teacher professional development, sometimes related to teacher learning, comes about through continuous reflection on one's own and others' educational beliefs and practices (Helleve 2009).

As illustrated in Figure 8, reformation of beliefs could, however, be considered to be initiated through increased awareness and knowledge of teaching and learning (Desimone 2009; Graber 1996; Schepens, Aelterman & Van Keer 2007). Based on the above discussions, it is therefore crucial that teacher education courses and programmes address these aspects by increasing awareness and knowledge of innovative methods and, furthermore, by providing student teachers with potential tools to plan, execute, analyse and reflect on their lessons.

As regards the above notions, increasing student teacher awareness was at the heart of the teacher education intervention, and all of the above components were explicitly present in the teaching programme. In particular, the student teachers acknowledged the concept of communicative approach as being a useful tool in reflecting upon their educational behaviour. Reflecting on this, it is considered that the basis of the teaching programme's success lay not in merely introducing the students to the scholarly definitions of dialogic pedagogy given in educational research, but, particularly, in adopting these aspects within each of the above-mentioned areas of practice.

Previous studies on science professional development programmes have already provided important insights into aspects such as designing appropriate lessons, adopting effective teaching methods, implementing specific instructional activities, and evaluating student learning (e.g., Akerson &

Hanuscin 2007; Luera & Otto 2005). One limitation of these programmes, however, is that they often overlook the social dimension of science teaching (Oliveira 2009, 2010a) and its integration into instruction (Borko 2004; Clarke & Hollingsworth 2002; Yilmaz-Tuzun 2007). When these social and integrative dimensions are overlooked, student teachers are often unable to effectively use the appropriate pedagogical strategies highlighted in methods courses.

Accordingly, as intended, the majority of student teachers within the designed teaching programme gained practical experience of implementing dialogic pedagogy. Compared to conventional science classrooms, the presence of the dialogic aspect was, at least, more frequent, thus enriching the observed teaching sequences with more versatile communication.

As regards continuing development and the above-mentioned concern regarding regression, however, in addition to indicating increased awareness about dialogic teaching and its successful implementation, the student teachers also highlighted the challenges that come with dialogic implementation. With regard to the main concerns reported by the student teachers, it has been discussed that the monologic style of teaching in science possibly originates from a lack of both subject and pedagogical content knowledge (Carlsen 1997; Childs & McNicholl 2007; Colucci-Gray & Fraser 2008; Newton & Newton 2001). This was particularly evident before the student teachers were introduced to intentional planning of different communicative approaches. At that stage, the student teacher lesson plans focused merely on covering the content, instead of the different ways that this content could be discussed. In the author's view, in order to overcome teachers' concerns regarding content knowledge, the overall orientation of science teaching should be shifted further away from content learning and more towards scientific inquiry. The social aspects of scientific inquiry should also be highlighted as a part of this process. After all, nowadays the vast majority of the basic work of science, including major scientific discoveries, is carried out in research groups.

Despite the controversial arguments concerning novices' likely regression without ongoing support (Luft & Patterson 2002), the evident change in the student teachers' communication awareness can be considered as a seed for more dialogic classrooms in the future. If this positively acknowledged awareness remains with the novices throughout their first years of real school experience, it is conceivable that they will be able to challenge the dominant school culture and practice dialogic science teaching. Overcoming the challenges this entails requires continuous reflection on gained pedagogical skills and experiences (Winizky & Kauchak 1995; Marbach-Ad & McGinnis 2008). In this respect, Roehrig and Luft (2006) suggest that continuing support should be provided for beginning teachers to facilitate the desired reformation. In Finland, this kind of support for beginning teachers is, however, very limited and unstructured. Liston, Whitcomb and Borko (2006) comment that preparation programmes lack sufficient theoretical basis to be applied in service. The teaching programme introduced in the present study, however, included explicit practical experiences that demonstrated the student teachers' ability to integrate the theory into practice. The hope is that this ability will remain intact and be put into practice when transitioning to the classroom.

Controversially with respect to previous notions about the development of student teachers' pedagogical practices, Kagan (1992) stresses that before novices can implement new practices in their teaching they must first establish control of the classroom. Grossman (1992) instead stresses that if student teachers are supposed to go beyond the technical aspects of teaching and question their practice, they should be guided towards doing so:

> If our goal is not helping prospective teachers attain an immediate mastery of classroom routines, but preparing prospective teachers to ask worthwhile questions of their teaching, to continue to learn from their practice, to adopt innovative models of instruction, and to face the dimensions of classroom teaching, then we must place our emphasis elsewhere. (p. 176)

In the line with the above quotation, the results of the present study indicate that even though student teachers are concerned about issues of discipline and time, they are already capable of challenging traditional forms of teaching during their teacher training in both theory and practice. It could be argued that because of the explicit weight given to communication, the student teachers were able to consider alternative approaches and also implement them in practice, albeit to varying extents, during teacher training lessons.

While the above-mentioned challenges on the path toward reformation of individuals' educational practice are very real, it may be hypothesised that if a teaching programme or course has a genuine positive influence on student teachers' views and awareness of dialogic teaching and learning, it will foster a change in their beliefs. This could lead to changes in practice regardless of whether personal or cultural challenges are faced in service. Figure 8, adapted from earlier illustrations (Desimone 2009), illustrates the route towards positive or negative change in educational behaviour within the study context of a one-year teacher education programme. In the figure, the one-way arrows indicate the path towards reformation/regression, while the double arrow between challenges and changes represents challenges occurring either before or due to changes in teacher practice (behaviour). In other words, when faced with the dominating school culture the teacher might not attempt to implement dialogic practices at all, or, upon coming up against resistance, the initially innovative teacher might revert towards a safer authoritative teaching style.

More generally, rather than being a straightforward process, reformation continues throughout the teacher's career in the form of an iterative cycle supported by systematic reflection on practice. It remains to be seen whether the student teachers involved in this study will continue on the path of reformation or regress. An essential consideration here is the impact of the challenges identified and how teachers can be prepared or supported to face them. This question should be at the heart of subsequent teaching programmes addressing teacher talk. Besides more concrete support from teacher tutors and mentors, also supplementary materials, such as specific teaching kits, could support the creation of more dialogic learning environments. The question of reformation/regression will be specifically addressed in forthcoming studies involving the participants of the present study in the in-service environment. It would also be worthwhile to study how experienced in-service teachers would welcome dialogic insights into their views, since it is not currently realised in the practice of classroom realities.

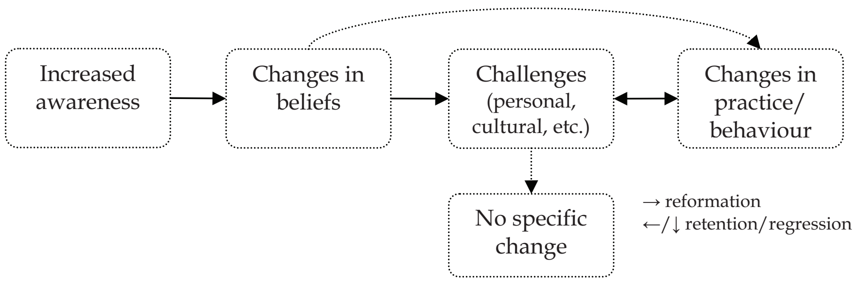

FIGURE 8 From increased awareness towards reformation or regression of educational behaviour

6.4 Implications for teaching and teacher education

Sociocultural theories are strongly present in the Finnish teacher education curriculum. However, ways to concretise and implement theory into practice are not sufficiently elaborated in teacher education, especially with regard to communication. In particular, the role of the dialogic aspect is not highlighted or explicitly practiced in science teacher education, even though its rationale originates from the essentiality of reciprocal and mutual interaction and authentic scientific inquiry. This study bridges this gap by introducing a teaching programme on teacher talk that includes a course on dialogic inquiry-based teaching and incorporates the social aspect of instructional communication.

As the programme can be considered to form gestalt forums in which novices can adopt new ways of teaching, it is not possible to say whether any single programme component had an expected effect. Neither it is discussed here whether any components could be omitted from the teaching programme. Thus, it shall be left to the judgement of teacher educators and further studies to determine which components of the exemplary programme would be beneficial to include in courses addressing the sociocultural approach and teacher talk.

Generally, the results support the use of practical components such as videos in varying situations, such as in practising the categorisation of communicative approaches and reflecting upon lessons, rather than overburdening student teachers with excessive theory. All in all, the dialogic status of science classroom realities and the pre-conceptions of student teachers call for teacher education interventions such as that presented in this study.

As discussed by Viiri and Saari (2006), the feedback student teachers receive from teacher tutors can be sometimes unstructured and vague. This is discordant with the observations of my pre-studies, which indicate that the teacher training school is a context in which dialogic teaching is implemented by science teacher tutors themselves. Feedback on student teachers' lessons does not, however, include explicit consideration of communicative approaches. In addition to videos, also lessons graphs offer a means of providing constructive feedback on student teacher talk. For example, monologic and authoritative lessons could in this way be easily detected and presented in lesson feedback and reflections.

The findings of this study demonstrate that as teachers become more aware of dialogic options they become more prepared to seize opportunities for extended dialogue in whole-class teaching. Moreover, in order to create an open classroom climate for dialogic discussion and emerging student utterances, teachers need to adopt an overall dialogic perspective in their teaching. Myhill (2006) describes the opportunities occurring in the classroom as "critical moments" in which the teacher either initiates extended dialogues or withdraws and takes authoritative control of the direction of the discussion. As highlighted in Article II, besides seizing opportunities to engage in dialogic discussions as they arise, the teacher can more systematically structure classroom communication through lesson planning in order to foster cumulative learning that embraces both aspects of communication.

The proposed framework for dialogic inquiry-based teaching could be utilised in the education of both student teachers as well as teachers already in service. As straightforward as the principles of dialogic inquiry-based teaching may seem, it is currently not made sufficiently clear how teachers should communicate within the different phases of inquiry. Moreover, communication within inquiries should not be seen as black or white, authoritative or dialogic. Instead, teachers should consciously react with an appropriate communicative approach in sync with the concurrent phase of inquiry. Since within popular scientific inquiry the role of the teacher is only vaguely described (e.g., co-inquirer) and communicational actions are not explicitly characterised, the teacher education intervention and framework for dialogic inquiry-based teaching introduced in this study offer solutions to address this gap in future research and teacher education. Furthermore, the framework serves as a structural basis for lesson planning, which, according to Zubrowski (2007), is elemental to implementing inquiry components in practice.

The theoretical integration of sociocultural background theory and meaningful learning of science suggests that teaching should take place within the ZPD during both the opening up and closing down phases. Moreover, as the ZPD often relates to teacher-orchestration, it should be expanded to the IDZ, for example, when authentic inquiry is intended to take place. In this sense, Figure 2 would theoretically represent teaching that emphasises the essentiality of spoken language as well as the students' role in meaningful learning of science. In other words, the teacher should embrace student contributions in different phases of the lesson through the application of different communicative approaches within the ZPD and, in addition, should also be sensitive to opening up spaces for more student-driven dialogic interactions taking place within the IDZ. This would result also in students taking more ownership of their science learning as they feel their ideas and efforts are valued.

6.5 Methodological implications

The methodological focus of this study was on analysing, interpreting and presenting classroom communications through a sociocultural lens. As an addition to previous work in this area, the study provides further developed and highly innovative ways of accessing and, especially, visualising the temporality of teacher talk. The developed lesson graphs illustrating the use of different communicative approaches provide a valuable overview of the communicative nature of lessons as well as detailed information on how talk develops and progresses over time. Moreover, the graphs explicitly illustrate the shifts between different forms of talk, thus revealing the rhythm of teacher talk. Furthermore, the graphs could be used as tools to map teacher-dependent communication structures over a lesson, course or series of courses, or simply to reveal similarities between different teachers teaching the same content.

While graphs serve as exquisite tools for scrutinising overall communication, transcription excerpts hold invaluable potential, offering readers fragments and snapshots of classroom realities. Indeed, depending on the aims of the researchers, micro-level examination at the sentence level may be the preferred approach. The major implication of Articles I and II is that analysis should be based on different layers of classroom interaction in order to establish trustworthy and complementary interpretations (Klette 2009). Temporal assessment could either involve proceeding from a wider temporal scale down to specific utterances (Article I), or vice versa, specific utterances and their relation to the context could be weighted by spreading the temporal scale across episodes and teaching sequences (Article II).

Article III introduces a novel approach to evaluating dialogic inquiry-based teaching. As inquiry guidelines are typically holistic, even vague, it became crucial to highlight the role of communication and teacher talk in scientific inquiries. Resonating with the idea of overall communication, by integrating the principles of dialogic teaching and the communicative approach into different phases of inquiry it is possible, using the appropriate communicative approaches, to structure the inquiry processes to meet the requirement for in-depth learning through scientific inquiry. The evaluation criteria for inquiry and communication, developed from the framework for meaningful learning, offer a unique way to evaluate inquiry-based teaching in both teacher conceptions and teaching processes.

7 CONCLUSIONS

While this research provides evidence that novice teachers can implement dialogic teaching, the classroom observations revealed that traditional "safe" authoritative forms of teaching remain deeply embedded in teacher practice. Examples of dialogic teaching were, however, identified, thus offering hope that the dialogic classroom is not inevitably out of reach. It should not be forgotten, however, that while the prevailing school culture may not be favourable towards the dialogic aspect of classroom communication, curricula aim to promote and justify dialogic interaction. The rationale for dialogic reform can be derived from the following simple question: Do we want to prepare future citizens that have a disjointed knowledge of school science, or citizens who are able to apply practised discursive and problem-solving strategies to realities outside the classroom? In the future, accessing information will not be difficult; rather the challenge will be in asking the right questions and evaluating the validity of answers. Moreover, as technology-based learning increasingly takes over, the need to maintain and develop social and verbal communicational skills will become ever more crucial. Classroom communication has a central role in developing these skills to meet future needs. Just as importantly, complex learning processes should be approached through purposeful and structured forms of teacher-orchestrated talk.

It is not argued that introducing teachers to alternative communicative approaches alone would be enough to bring about reformation of teaching practices. Moreover, students cannot be expected to immediately engage in extended dialogic discussions if they lack the ability to participate in constructive and sophisticated forms of communication. As it is seen within this study, whereas the principles of dialogic teaching offer a holistic perspective with respect to offering students' an active presence in teaching and learning processes, the communicative approach maintains the idea that science teaching necessarily includes both sides of communication: authoritative and dialogic. The tension between these two approaches requires a coherent chain or cumulation of actions and communication in order to facilitate the complementary features of these fundamentally different approaches. This aspect needs further theoretical development, as temporal concepts such as cumulation are not yet sufficiently described, at least in science education literature. One of the few related ideas is the opening up/closing down structure, which is central to the framework of cumulative communication structure conceptualised further in this study.

According to this doctoral research, the examination and implementation of communication should take account of various external factors as well as the epistemological norms of the topics under discussion. In other words, whereas elements of dialogic teaching are essential in creating an open atmosphere for emerging students' utterances and mutuality, the communicative approach, alongside temporal consideration, offers a more explicit way of planning, executing and evaluating science teaching sequences. As said, awareness alone is not sufficient for developing dialogic exchanges. Nevertheless, it is a more than necessary step towards educationally purposeful and versatile communication in science classrooms.

8 LIMITATIONS AND ETCHICAL ASPECTS

The teaching programme addressing teacher talk and the course on dialogic inquiry-based teaching introduced within this study aimed to enrich student teachers' views of science teaching by increasing their awareness of dialogic teaching. With regard to this aim, however, teacher educators should be mindful of ethicality when addressing student teachers' prior beliefs (Raths 2001). Within this research the purpose was not to teach "new" or "better" beliefs, but rather to introduce student teachers to alternative approaches to teaching and, through this, and facilitated by the experimental activities included in the teaching programme, to initiate the reformation of views and practices.

In keeping with ethical requirements, written permission to collect and use data for research and educational purposes was obtained from all voluntary participants. In addition, participants had the right to withdraw at any point without further obligation (British Educational Research Association 2011) or to participate partially. For example, if a student teacher did not wish to be video recorded, he/she could still take part in other activities executed within the course. Pseudonyms were used in publications in order to preserve the anonymity of the participants.

As the participation of the author in planning and executing the teaching programme was unavoidable, *objectivity* was called into question by several reviewers during the review process. However, in order to establish objectivity, varying approaches were applied to ensure the trustworthiness of the interpretations. In addition to the use of researcher triangulation to address agreement issues to minimise bias (Gee 1999), the interpretations were also openly shared with the participant student teachers. More specifically, a *member check* was applied in order to validate, in particular, the results involving interpretations of interviewer-interviewee interactions and student teacher behaviour (Lincoln & Guba 1985).

With regard to objectivity, the theoretical background should be made visible to readers in order to unveil the origin of the interpretations. More importantly still, the theoretical positioning should be clear to the researcher so that he/she would not be limited by the theoretical framework. It has been an important aim of this dissertation and each of the articles to introduce the theoretical background and related concepts with sufficient *precision* in order to provide the reader with the appropriate contextual knowledge to understand the results and interpretations.

The project can be considered to support the *openness* of scientific research. The project plans were introduced at several national and international meetings and conferences and the preliminary results were similarly presented. In addition, drafts of the articles were commented on by professional researchers in the same research field. In this way, the project can be considered as being monitored by the research community (NRC 2002). The issue of "inevitable subjectivity" was addressed and discussed already during the process, rather than merely at the end (Peshkin 1988). Resonating with Peshkin's (1988) notions, highlighting the issue of subjectivity increased awareness of the origin of the interpretations, which is also essential in revealing and avoiding the biases that qualitative research brings with it.

As the issue of subjectivity was relevant already during composing the transcriptions and translations, it was necessary to maintain the linguistic detail and tie the conclusions to these details (Gee 1999). Although the analysis was initially supported by videos, transcriptions were an essential part of the final data analysis and presentation. The transcriptions were conducted by several researchers, although the final selection of excerpts was done by the author. The Finnish to English translations were compiled by the author, but were discussed with and modified by a native English colleague with a good knowledge of Finnish. Thus, cultural differences in communication could be considered and the authenticity of the translations was given close consideration (Nikander 2008).

To summarise, it can be said that the above-mentioned procedures and standards, such as *triangulation, member check, precision* and *openness*, demonstrate the credibility and reliability of the study (Lincoln & Guba 1985).

As regards the limitations of the study, it should be noted that the number of participants was relatively small, although not exceptionally so for a study specific to Finland. Finally, as a major limitation, it is not possible to conclude whether the student teachers who took part in the teaching programme would continue towards reformation or regression when beginning in-service teaching. However, this offers an opportunity for future studies examining the views and implementation of dialogic teaching of the participants of this study in the in-service environment.

YHTEENVETO

Tässä tutkimuksessa dialogista opettamista tutkittiin luokkahuone- ja opettajankoulutuksen konteksteissa. Tutkimuksen tavoitteena oli tarkastella miten dialogisuus näkyy osana opettajaopiskelijoiden luonnontieteiden opetusta ja selvittää opettajan puheeseen liittyvän ohjelman vaikutusta heidän näkemyksiinsä. Tutkimuksessa tarkasteltiin myös kentällä työskenteleviä opettajia ja pohditaan, kuinka opetusharjoittelun kautta voidaan vastata kentällä vallitseviin yksipuolisiin vuorovaikutuksen muotoihin. Dialoginen näkökulma ymmärretään osana vuorovaikutuksellisempaa ja vastavuoroisempaa kommunikointia, jossa erilaisille ajatuksille annetaan oma sijansa luokkahuonekeskusteluissa. Dialogisuudella tarkoitetaan ennen kaikkea eri näkökulmien huomioimista. Vaikka tässä tutkimuksessa nostetaan esille dialoginen näkökulma, luonnontieteiden merkityksellinen oppiminen sisältää myös perinteisemmän auktoritatiivisen lähestymistavan, jolla on tärkeä rooli tieteellisten johtopäätösten ja yhteenvetojen muodostamisessa.

Luokkahuonekommunikaatiota tarkasteltiin sosiokulttuurisesta näkökulmasta. Sen mukaan merkityksellinen oppiminen tapahtuu vuorovaikutuksessa kanssaihmisten kanssa ja luokassa erityisesti opettajan ja oppilaan välisessä vuorovaikutuksessa. Sosiokulttuuriseen teoriaan pohjautuen jo pelkän suullisen kommunikoinnin on esitetty edellyttävän korkeamman tason ajatusprosesseja. Toisin sanoen luokkahuonekeskustelut sellaisenaan vaativat korkeamman tason ajattelua, ja vaikka opettaja on vuorovaikutuksessa koko luokan kanssa, voivat kollektiiviset keskustelut paljastaa ihmisen ajattelua myös yksilön tasolla. Dialogisessa opettamisessa pyritään vähentämään luokkahuonevuorovaikutuksen arvioivaa luonnetta ja väärän vastauksen pelkoa. Samalla oppilaita pyritään aktivoimaan oppimisen tavoitteiden kannalta rakentaviin keskusteluihin.

Tutkimus koostuu neljästä kansainvälisestä artikkelista sekä teorian, metodin ja tulokset kokoavasta yhteenveto-osuudesta. Yhteenvedossa keskustellaan tuloksista myös laajemmassa valossa, kun tarkastellaan opettajankoulutuksen mahdollista vaikutusta opettajan puheeseen luokkahuoneen arjessa. Tutkimuksen aineisto koostuu kentällä työskentelevien yläkoulun matemaattisluonnontieteellisten opettajien pitämistä tunneista, fysiikan opettajaopiskelijoiden Jyväskylän yliopiston normaalikoululla pitämistä oppitunneista, sekä luokanopettajaopiskelijoiden kaupungin kouluissa pitämistä tunneista. Lisäksi opettajaopiskelijoita haastateltiin tutkimuksen eri vaiheissa heidän näkemyksistään dialogisesta opettamisesta. Fysiikan aineenopettajaopiskelijoista aineistoa kerättiin lukuvuosina 2007-2008 ja 2008-2009. Luokanopettajaopiskelijoista aineistoa kerättiin lukuvuonna 2009-2010. Kentällä työskentelevien opettajien osalta aineistoa kerättiin lukuvuonna 2008-2009. Luokkahuonevuorovaikutusta analysoitiin videoilta sekä aikaan perustuvan koodauksen avulla että laadullisemman episodiperustaisen analyysin avulla. Analysoitavan yksikön valinta perustui artikkeleiden yksittäisiin tutkimuskysymyksiin. Yhteisenä tekijänä videoiden analysointiin ja tulosten esittämiseen liittyen voidaan pitää muodostettuja tuntikuvaajia, jotka mahdollistavat kommunikatiivisen kokonaiskuvan esittämisen sekä kommunikatiivisten rakenteiden havainnollistamisen. Toisin sanoen keskiössä ei ollut pelkästään se missä määrin tietyt kommunikatiiviset lähestymistavat esiintyvät, vaan myös miten puhe kehittyy ja etenee opetusjakson aikana. Haastatteluaineiston analysoinnissa ja tulosten esittämisessä hyödynnettiin temaattista analyysiä, joka mahdollistaa suurten haastatteluaineistojen joustavan analysoinnin ja tulosten tiiviin esittämisen.

Tutkimus koostui artikkeleissa esitetyistä tutkimuskysymyksistä, jotka voidaan tiivistää kolmeen pääkysymykseen:

1. Kuinka dialogista vuorovaikutusta ilmenee luonnontieteiden oppitunneilla?
2. Kuinka opettajaopiskelijat omaksuvat dialogisen opettamisen osana luonnontieteiden opettamista?
3. Kuinka opettajaopiskelijat toteuttavat dialogista opettamista oppitunneilla opetusharjoittelun aikana?

Tutkimus osoitti, että fysiikan aineenopettajaopiskelijat omaksuivat dialogisen opettamisen osaksi luonnontieteiden opettamista ja oppimista. He pitivät osallistumistaan koulutusohjelmaan hyödyllisenä ja totesivat sen rikastuttaneen heidän ajatuksiaan eri kommunikatiivisista lähestymistavoista ja niiden merkityksestä. Samalla he kuitenkin toivat esille haasteita liittyen dialogisen lähestymistavan soveltamiseen kentällä. Haasteina pidettiin esimerkiksi luokkahuonejärjestyksen hallintaa, ajankäyttöä ja opetettavan aineen sisältötiedon hallintaa. Haasteisiin ja tutkimuksen yleisiin havaintoihin liittyen voidaan todeta lisäksi, että vallitseva luokkahuonekulttuuri luonnontieteiden opetuksessa on edelleen varsin auktoritatiivinen riippumatta opetussuunnitelmiin sisällytetyistä oppilaslähtöisemmistä suuntauksista. Vaikka tutkivan oppimisen periaatteita on sisällytetty osaksi luonnontieteiden opetussuunnitelmaa, tutkivan oppimisen sosiaalinen puoli on edelleen puutteellisesti esillä opetuksessa.

Edellä mainittuun puutteeseen pyrittiin vastaamaan dialogisen tutkivan opettamisen kurssilla, jossa huomioitiin kommunikatiivisten lähestymistapojen suunnitelmallista käyttöä opetusjakson aikana. Tulokset osoittivat, että vaikka luokanopettajaopiskelijat omaksuivat dialogisen lähestymistavan osana tutkivaa oppimista, käytännön toteutuksessa oli suurta vaihtelua. Lisäksi opetus nähtiin mustavalkoisesti joko auktoritatiivisena tai dialogisena, kun merkityksellisen oppimisen pitäisi koostua molemmista lähestymistavoista.

Tutkimuksen johtopäätöksenä esitetään, että opettajan puheen ja kommunikoinnin tarkoituksenmukainen ja täsmällinen esille tuominen opetusharjoittelun aikana on välttämätöntä, jotta vallitsevat luokkahuonekeskustelun normit voitaisiin haastaa. Opettajaopiskelijoiden analysoidut haastattelut ja oppitunnit paljastivat, että heidän tietoisuutensa kommunikatiivisista lähestymistavoista ja dialogisesta opettamisesta olivat lisääntyneet. Tulevaisuuden haasteisiin liittyen dialogisen lähestymistavan sisältävä luokkahuonekommunikaatio tukee kriittisten ajattelijoiden koulutusta nyky-yhteiskuntaa varten, jossa tiedonhaku ja tiedon muistaminen eivät ole enää ongelma. Sen sijaan oleellisempaa on tiedon kriittinen tarkastelu ja käsitteleminen myös sosiaalisissa tilanteissa.

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ORIGINAL PAPERS

I

VISUALISING COMMUNICATIVE APPROACHES IN SCIENCE CLASSROOMS

By

Sami Lehesvuori, Jouni Viiri, Helena Rasku-Puttonen & Jussi Helaakoski
submitted

II

INTRODUCING DIALOGIC TEACHING TO SCIENCE STUDENT TEACHERS

By

Sami Lehesvuori, Jouni Viiri & Helena Rasku-Puttonen 2011

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INTRODUCING DIALOGIC TEACHING TO SCIENCE STUDENT TEACHERS

Sami Lehesvuori, Jouni Viiri & Helena Rasku-Puttonen

Abstract

It is commonly believed that science teachers rely on language that allows only minor flexibility when it comes to taking into account contrasting views and pupil thoughts. Too frequently science teachers either pose questions that target predefined answers or simply lecture through lessons, a major concern from a sociocultural perspective. This study reports the experiences of science student teachers when introduced to the Communicative Approach to science education drawing on dialogic teacher-talk in addition to authoritative teacher-talk. This approach was introduced to the students in an interventional teaching program running parallel to the student teachers' field practice. The practical implications of this approach during initial teacher education are the central focus of this study. The data consisting of videos of lessons and interviews indicate that the student teacher awareness of teacher-talk and alternative communicative options did increase. Student teachers reported greater awareness of the different functions of teacher-talk as well as the challenges when trying to implement dialogic teaching.

Keywords: Science teacher education; teacher-talk; dialogic teaching; Communicative Approach

Introduction

The importance of productive classroom practices leading to positive learning outcomes is widely acknowledged and the teacher's role in promoting dialogic interaction has been demonstrated in many previous studies (Littleton & Howe, 2009; Mortimer & Scott, 2003; Wells & Arauz, 2006). While learning is likely to be most effective when children engage in the cognitive restructuring of their own knowledge and understanding (e.g., Wells, 2007) moving towards more dialogic teaching is challenging, especially for science teachers (Scott, Mortimer, & Aguiar, 2006). As improvements in schools are assumed to result from changes in teacher education, demands for improvements in teacher education have increased and the ways in which teachers are educated have been challenged (Bransford, Darling-Hammond, & LePage, 2005). In response to this demand, this study explores science student teachers' experiences of dialogic teaching and the practical implications of dialogic teaching during initial teacher education.

In response to the sociocultural view of teaching and learning, researchers have introduced the concept of 'dialogic teaching' (e.g., Alexander, 2006; Nystrand, Gamoran, Kachur, & Prendergast, 1997). Dialogic teaching differentiates conversation from dialogue in terms of what follows from pupil answers (Alexander, 2006). In dialogic teaching exchanges are chained into coherent lines of enquiry rather than left disconnected. In science, dialogic teaching can be understood, not only as supportive and reciprocal interaction between participants in the classroom but as teachers orchestrating the dialogue between diverging ideas, for example, between everyday views and science's views (Lemke, 1990; Mortimer & Scott, 2003). To characterize these different forms of classroom talk and to provide a tool for the effective orchestration of classroom interaction, Mortimer and Scott (2003) developed the concept of the Communicative Approach particularly relevant to science education. This framework consists of four classes generated from two dimensions: interactive/non-interactive and authoritative/dialogic. The first dimension allows for student participation through interactive talk whereas non-interactive talk is monologic indicative of, for example, a lecture. The second dimension introduces the dialogic approach which takes into account diverging ideas and the authoritative approach which focuses on a specific point of view, usually the science view, presented by the teacher. The combination of these two dimensions forms the concept of Communicative Approach (CA) of Mortimer and Scott (2003).

While authoritative approaches are relatively easily found within science education research and hold an important place in classroom communication, dialogic approaches are more uncommon (Mercer, Dawes, & Staarman, 2009). Nevertheless, elements of dialogic teaching, such as questioning to stimulate and extend pupils' thinking (Chin, 2007) and elaborating on pupil responses, have been reported as valuable motivational factors in science education. When pupils have opportunities to present and challenge their pre-existing views against the scientific view, pupils can more easily see the lack in their understandings and are more willing to adopt new insights (Posner, Strike, Hewson, & Gertzog, 1982). Scott and Ametller (2007) suggest that the meaningful learning of science involves teachers creating space for dialogic discussion before introducing and concluding the discussion with the authoritative voice of science. Indeed some preliminary results indicate that combining authoritative and dialogic approaches is the most beneficial for pupils' learning outcomes (Furtak & Shavelson, 2009).

The focus in teacher education has been shifting towards more pupil-centred teaching methods (e.g., Peters, 2010), however, observation studies reveal minor changes in the field. Classroom interaction is still commonly dominated by lecturing or closed questions followed with evaluative feedback (e.g., Mercer et al., 2009; Molinari & Mameli, 2010) typically defined as the IRF-pattern, in which *I* stands for *teacher's initiation, R* for *pupil's response* and *F* (sometimes *E* for *evaluation*) for *teacher's feedback* (Lemke, 1990; Sinclair & Coulthard, 1975). In order to expand and vary the classic lecture and transmission modes of science education, inadequate for developing pupil understanding, teacher education needs ways of teaching teachers in the field of classroom interaction (Crespo, 2002). Arguably this is a lifelong process, but in order to initiate this development, the theory and practice within this field should first be introduced during pre-service training. Pre-service training is especially important if this is the most effective way of introducing change into in-service teaching practice (Bransford et al., 2005). Although learning to teach is a complex process, steps should be taken to develop teaching programs to give novice-teachers the opportunity to learn and practice alternative forms of teaching (Graber, 1996).

Pre-service teacher perceptions of teaching are largely based on their own experiences in school as pupils (Abell, 2000). Unless these perceptions are explicitly addressed, the danger exists that these beliefs persist throughout teacher education and into in-service teaching (Fajet, Bello, Leftwich, Mesler, & Shaver, 2005). Lecture-based professional development programs which 'transmit' knowledge and lack integrated instruction (Abell, 2000) often fail to access student teachers' pre-existing needs for professional development (Chval, Abell, Pareja, Musikul, & Ritzka, 2008). Traditional approaches to science education foregrounding the authoritative voice can effectively quash attempts to develop dialogic interaction if the role of dialogic interaction is insufficiently addressed. In response to these concerns, the specific aim of the teaching program on dialogic practices was to explicitly bring forth student teachers' pre-existing views on teaching and learning, and to provide opportunities for the discussion and practice of new pedagogical insights within the context of the Communicative Approach.

Research on social aspects of science teaching in professional development programs is limited. One example, however, is Oliveira’s (2009) examination of how elementary teachers’ increased awareness of inquiry-based questioning influenced their behavior. Oliveira's study indicated that teachers became far more aware of the different functions questions can serve. The elementary teachers recognized that in addition to serving cognitive ends questions also serve social functions, for example, encouraging pupils to articulate their own ideas. Teachers used questions that included social aspects twice as frequently following the two-week intervention. Another social aspect of teaching which has been studied is the ‘neutral acknowledgment’ of pupil responses to foster pupils’ exploration of different points of view and to encourage pupils to keep talking (van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001). These non-evaluative, neutral and supportive features of question-based discourse are perhaps the most accessible practices of dialogic teaching and are a focal point of the study reported here too. This study also addressed the need to provide student teachers with opportunities to examine and practice dialogic elements of teacher-talk, such as neutral questioning, during pre-service (Mortimer & Scott, 2003; Orland-Barak & Yinon, 2007). Although preliminary results indicate that student teacher communications can be enriched when purposefully guided (2nd Author et al., 2006), few studies report on teacher education programs and method courses specifically addressing how teacher-talk can be taught to student teachers and practiced during pre-service. Furthermore, the ways student teachers embrace the content of innovative teaching programs both in theory and practice is also insufficiently addressed. It is this lack that the present study hopes to address.

Research Questions

Previous studies on science professional development programs provide important insights into aspects such as designing appropriate lessons, adopting effective teaching methods, following particular instructional activities, and evaluating student learning (e.g., Akerson & Hanuscin, 2007; Luera & Otto, 2005). However, one limitation of these programs is that they often overlook the social dimension of science teaching (Oliveira, 2009; Oliveira, 2010) and the integration into instruction (e.g., Borko, 2004; Clarke & Hollingsworth, 2002; Yilmaz-Tuzun, 2008). When these social and integrative dimensions are overlooked, student teachers are often unable to effectively use the appropriate pedagogical strategies highlighted in methods courses.

In this study the aim was to explicitly address these social and integrative dimensions in pre-service science teacher education. These dimensions come together in the dialogic focus of this study with the research questions:

1) How did student teachers plan and implement dialogic teacher-talk in science education during their pre-service field practice?
2) How did student teachers experience dialogic interaction and its implementation?

In general terms we see this focus on dialogic teaching as being fundamentally important to bring forth in the context of science teacher education.

Method

The Context and the Participants

The context of this study includes three facilities of the University: the Department of Teacher Education, the Teacher Training School, and the Physics Department. The researchers themselves belong to the Department of Teacher Education responsible for the pedagogical studies for subject and class teacher education at the university. It was under the auspices of the Teacher

Education Department that the first author planned and executed the dialogic teaching program. The tutor teachers are staff of the Teacher Training School responsible for overseeing the field practice of student teachers. The student teacher participants belonged to both the Department of Teacher Education and the Physics Department as during pre-service teacher training subject and pedagogical studies are conducted in parallel. The one-year pedagogic period includes the necessary pedagogical studies to qualify students as subject teachers after finishing their Master's degree. Student teachers may have some experience as substitute teachers prior to their teacher education, but many student teachers start their pedagogical studies with no teaching experience. Student teachers usually study their major subject, alongside other minor subjects such as mathematics and chemistry, for three-four years prior to teacher education.

At the beginning of the academic year of 2007-2008 (Oct-May), the dialogic teaching program was introduced in general to all of the 15 student physics teachers and the invitation for volunteers was made. Six individuals volunteered after the introductory session and Anthony, David, Kevin, Maria, Paul and Susan completed the dialogic teaching program as presented in the left column of Table 1.

In the following academic year (2008-2009), 6 physics student teachers, George, Rosanna, Lea, Mark, Melanie, and Joanna, were introduced to the improved teaching program in an information session. All of the students volunteered, although Lea joined with the proviso not to be video-recorded. In total, 12 out of 21 physics student teacher voluntarily participated in the teaching program during semesters 2007-2008 and 2008-2009. All of the names are pseudonyms in order to maintain absolute anonymity. When selecting the pseudonyms common English names were chosen to help international readers identify the gender of the participants. The participants provided written permission to present the data related to this project.

The Teaching Program

The aim of the teaching program on dialogic practices was to explicate the student teachers' pre-existing views on teaching and learning, and to provide the student teachers with opportunities to discuss and practice new pedagogical insights via various activities. This teaching program did not intend to model complex reflective instructional decision-making and planning (Schön, 1983), rather the aim of the intervention was to explicitly address the developing views of the student teachers. The phases, duration and related activities of the program are listed in Table 1.

Table 1 Phases and activities of the teaching program

	Phases and Activities of the Teaching Program 2007-2008	**Related activities and improvements for the semester 2008-2009**
Oct ↓	Theory • Instruction including theoretical background and the CA concept (2 hours)	Improvement: -Video clips from semester 2007-2008
	Observations • Two teaching sessions. One physics lesson taught by peer and 1 lesson by tutor teacher in teacher training school • Written report by student teacher on observations • Group discussion between researcher and the student teachers on the observations (2 hours)	Improvement: -Improved observation forms and instructions for classroom observations
	Planning and Implementing • Two physics teaching sessions including written lesson plans completed by individuals following the instructions of the researcher	Improvement and Related activity: -Peer videoing
	Reflections • Guided reflective feedback sessions with the researcher based on the stimulated recall interview technique after each teaching session	Related activity: -Small scale research • About teacher-talk using the CA and video data from student teacher lessons (own & others') • Supervised by the physics pedagogue Both semesters
May	Group interview (2 hours) • Discussions between researcher and student teachers about the teaching program and the CA concept	

The general aim of the program was to maintain the presence and practice of the CA during each phase (e.g., theoretical instructions, practical activities, and reflective feedback sessions). The basis of the teaching program was the same for both periods (2007-2008 & 2008-2009) although using the results of 2007-2008 a number of small improvements were made, as presented in Table 1. One change was that instead of the researcher video-recording the student teacher lessons, the videoing was done by peers. The peer-videoing reduced the evaluative atmosphere during the implementation phase, an improvement suggested by the student teachers. This change in turn created the opportunity for the student teachers to be empirical researchers of their own professional development, which may provide “a catalyst for reflection and critical dialogue among student teachers” (Hartford & MacRuairc, 2008, p. 1890).

Another significant change in the second teaching program, and surely an improvement, was the inclusion of the video database from the 2007-2008 semester. Selected authentic video clips were used during the theory phase. The student teachers first commented on the clips prior to being introduced to the CA concept and then again once familiarized with the CA concept. Videos were used as they especially capture the richness of classroom events (Brophy, 2004; Rosaen, Lundeberg, Cooper, Fritzen, & Terpstra, 2008) and can be effectively used for later analysis. Videos have also been successfully used to create an environment in which to engage teachers in productive discussions about teaching and learning, in order to foster professional development (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Hartford & MacRuairc, 2008).

The first author provided the student teachers with guidance and tutoring in general, but had no input regarding the content and execution of the lessons apart from providing a basic structure for planning episodes and teacher-talk. The structure for planning the episodes was derived from the analytical framework for analyzing science teaching interaction developed by Mortimer and Scott (2003). This structure includes the consideration of the topic, purpose, implementation and communicative approach. Whereas David did not follow this structure in his lesson plan, Paul's lesson plan illustrates this structure in Appendix A. Within this structure explicit question prompts are not written down, rather the implementation of this dialogic approach requires teachers to pre-consider open questions and to anticipate the need for supportive or neutral feedback. The lessons were conducted under the supervision of the tutor teacher usually without any intervention or support. Based on the first author's own experiences as a student physics teacher with the same tutors and the interview with the collaborating tutor teacher Mr. James, dialogic teaching is not explicitly addressed by the teacher training school.

Data Collection and Analysis

This paper includes the analysis and presentation of data as shown in Table 2. The complete data-set was analyzed and the cross-sectional view of the data presented here is intended to allow the exemplification and discussion of the overall project within the limitations of an article. The findings are, therefore, presented at both cross-case and collective levels. The illustrative examples of individual student teachers presented and discussed below are then the focus of the summaries of the collective experiences of the student teachers. These collective experiences emerged as the group discussed their observations as well as in the group interview which included all of the participants of the semester.

Table 2 Data analysis and presentation

Research question	Data analyzed	Data example	Analytical methods
1) How did student teachers plan and implement dialogic teacher-talk during their pre-service field experience?	All video-recorded lessons including lesson plans	Dialogic episodes and lesson plans of David and Paul and summary of all student teachers	Video analysis
	All reflective feedback session interviews	David and Paul comment on their lessons	Discourse analysis
2) How did student teachers experience dialogic interaction and its implementation?	Introductory lessons of the teaching program 2008-2009	Student teachers comment on previous video-excerpts of David and Paul	Data-driven thematic analysis
	Semi-guided group interview of both semesters	Student teachers discussions on the teaching program and dialogic teacher-talk	

Two lessons from each student teacher were video recorded and analyzed. The limited number of video recordings was due to two reasons: Firstly, student teacher lessons are often scheduled parallel to each other, thus there was a lack of researcher resources. Secondly, as the teaching program was integrated within an already intensive teacher training curriculum it was not desirable to strain student teachers with an excessive number of obligatory reflections and peer videoing. The codes for the video analysis were derived from the communicative approaches described by Mortimer and Scott (2003):

- Interactive Authoritative (I/A): Question-answer routines often feature in the I/A class with pupil responses often being evaluated in-line with the authoritative view of science leaving little space for the consideration of alternative or diverging ideas.
- Interactive Dialogic (I/D): Student ideas (e.g. everyday views) are intentionally explored and exploited with no evaluative aspect. When working within the I/D class the teacher does not seek a specific point of view, rather the teacher purposefully elicits student perspectives and works with these contrasting views.

- Non-Interactive Authoritative (NI/A): The teacher explicitly presents the scientific view, often by lecturing, without addressing contrasting views.
- Non-Interactive Dialogic (NI/D): The teacher works with contrasting views, perhaps previously expressed pupil perspectives, and intentionally moves towards the scientific perspective. In the NI/D class while the teacher may lecture, diverging ideas are still present and the way in which the teacher-talk manages both the everyday and expert understandings means that the teacher-talk is dialogic in nature.

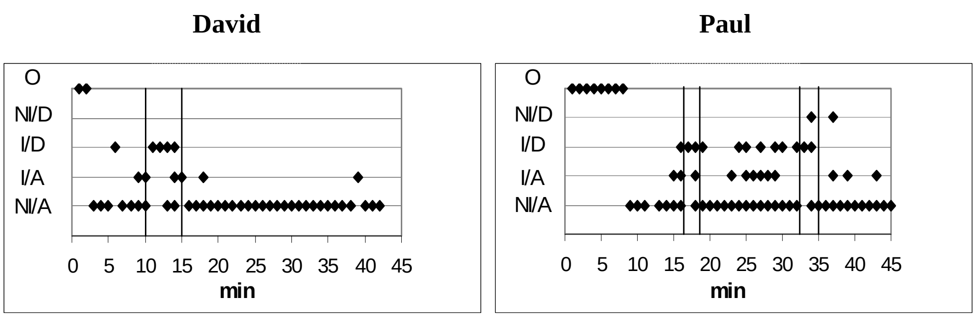
Coding was done each 20 seconds and 'micro-scale' indicators for the communicate approaches (e.g. teacher feedback) were considered, thus one minute in the figures could include several communicative approaches in terms of codes: For example, a dialogic episode could include authoritative passages which aim to guide the direction of discussions. An episode in general is defined by considering the activity, topic, teaching purpose and intervention taking place. Within a dialogic episode the predominant communicative approach is dialogic as defined by Mortimer and Scott (2003), although authoritative turns to guide the discussions may occur. The reliability and validity of our video analysis was checked by selected parts of lessons, including 'richly' different communicative approaches, being video coded by two coders independently. Cohen's Kappa was used to indicate the inter-rater reliability in conjunction with the statistical program SPSS. A Cohen's Kappa value of 0.788 ($p<0.001$) indicates that the inter-rater reliability can be considered satisfactory for our purposes. Differences in coding were discussed and when agreement was achieved the coding of those parts was revised. The primary tool used for the overall analysis was the *AtlasTi*-software which, whilst designed for qualitative analysis, can also be used for quantitative procedures.

Extracts of transcribed talk from the activities listed in Table 2 allow readers to evaluate the analysis and findings presented in the following sections. The match between excerpts, themes and interpretations, were peer debriefed among the local community of educational researchers including the authors (Miles & Huberman, 1994). Furthermore, international researchers within this line of work provided their commentary on the draft. The data was also shared with the student participants who responded to their university e-mail (Anthony, Joanna, George, Mark, Melanie and Paul) so that ‘member check’ of the transcriptions and interpretations was also applied in the validation process (Lincoln & Guba, 1985).

Findings

Research Question 1: How did student teachers plan and implement dialogic teacher-talk during their pre-service field practice?

Planning, implementation and reflection: individual student teacher examples. This section includes overviews (Figure 1) from Paul’s and David’s lessons, with one transcribed and translated episode from each lesson followed by student teacher and then researcher comments. These excerpts are also used in the later discussion on student teacher pre-conceptions of teacher-talk. David’s example is from his first video-recorded lesson. At this point David had no detailed information why he was video-recorded. David and Kevin joined the teaching program during the first feedback session. Thus, they did not know they were being observed for the presence or absence of dialogic interactions during the first video- recorded lesson. In contrast Paul had specifically focused on the CA when planning his lesson. These different orientations to talk are visible in both the overviews of the lessons (45min) and in the feedback sessions. As can be seen in Figure 1 below, the structure of Paul’s lesson indicates dialogic instances at several points in the lesson, whereas David’s lesson includes only brief attempts to initiate dialogic interaction at the beginning of the lesson (coded as I/D turn at min 6, see excerpt below) and in the introduction to a new topic, electromagnetism (10-15min). Whereas David's lesson figure indicates one dialogic episode (10-15min), two dialogic episodes were confirmed in Paul's lesson (16-17min & 33-35min). Coded dialogic turns in Paul's lesson between minutes 24-30 are not sufficient in constituting episodes as dialogic since the prevailing approach is still authoritative.



The horizontal axis shows time in minutes and the vertical axis the Communicative Approach: NI/A = non-interactive authoritative, I/A = interactive authoritative, I/D = interactive dialogic, NI/D = non–interactive dialogic. O stands for other actions such as general announcements from the central speaker. Dialogic episodes are displayed within vertical lines.

Figure1. Overviews of Paul's and David's lessons

David's Lesson Excerpt and Reflective Feedback Session: David's lesson in the training school was for 8th grade (14-15 years) secondary school students. The following extract is from the beginning of a lesson on electricity and includes David giving neutral feedback to pupil responses. The absence of the extended implementation of dialogic talk is even more apparent when compared to Paul's excerpt illustrated later.

David's lesson excerpt: Domestic devices in parallel

1 David: And how do you think the stereo system operates, if you think…don't think too hard! If you have a flat-iron there and you are using it. You have the stereo system there and you

disconnect the flat-iron…what happens to the stereo system? Well, no-one has that kind of stereo system anymore but anyhow… (pause). Does the volume get louder, as though more current would flow in there or…?

2 Student: It gets quieter, I guess.

3 David: Quieter? (repeats with rising intonation and waiting for an extension)

4 Charlie: Well, less current goes there…because then…there goes only that 0.2 amperes and that's why …

5 David: If we think about that in a slightly different way…then the more apparatuses I plug in, the louder the stereo will be. For example, if I put another stereo system into that empty socket (shows picture) …

6 Charlie: Well because there will be… more current would flow in the circuit.

7 David: Yes (not evaluating). …The thing is…that the sockets…erm…Is it like…like…erm …the current that flows in the circuit is for different stereo systems, so if you unplug one…or if you unplug that flat-iron, the efficiency of the stereo system still stays the same. In a way the stereo system has its own current that flows there… and the current stays the same. The current doesn't change…(pause). That is the correct answer. (Transcribed and translated by the 1st author)

Comments: The question about predicting what happens when the flat-iron is unplugged was neutral, open-ended (turn 1) and David's reaction to the student's incorrect answer was non-evaluative (turn 3). As the excerpt from the feedback session confirms, David acknowledged what the pupil had to say but after a short, clear pause moved the talk on emphasizing the correct answer:

David: There I made a mistake…I got feedback from my tutor teacher (Mrs. Hill). The camera just turned away when I was nodding all the time the pupil was giving an incorrect answer…He answered that if you disconnect the flat-iron then less current is conducted through the stereo system… Like the same current would have been conducted to every part of the circuit. And there I even said, "yes". (Clearly not evaluating but declaratory)

Facilitator: So did you accept the answer?

David: Well…for some reason I didn't want to…I was somehow afraid that I would discourage him…I didn't want to evaluate him immediately and for some reason. I just nodded and said "yes" although I didn't accept the answer as a correct one. And I later presented, as far as I remember, what the correct answer was. (Transcribed and translated by the 1st author)

This episode could be considered to include minor characteristics of dialogic interaction, such as the non-evaluative feedback. As David's comment reveals, however, he had no clear idea why to do this. David mentions not wanting to discourage the pupil, but his comments do not reveal awareness of other benefits this kind of prompting can lead to, on the contrary David and his tutor teacher (Mrs. Hill), considered it a mistake. From a sociocultural perspective, this excerpt can be seen as an (unintentional) attempt to initiate dialogue. David's lesson plan

(Appendix A) revealed no intentional talk-based interaction or other discursive strategies. For David, as for many student teachers, the focus was on the lesson content and structure. These notions might be obvious, yet the importance of awareness and intentional planning for talk-based interaction needs to be highlighted to be realized.

Paul's Lesson Excerpt and Reflective Feedback Session: This episode includes a pre-planned dialogic episode, which Paul initiates with a simple demonstration of a bouncy rubber ball (min 33-35). Paul's lesson was part of the second physics course in upper secondary school on the topic of thermophysics. The lesson dealt with the laws of thermodynamics.

Paul's lesson excerpt: Bouncy rubber ball

1	Paul:	What happens (drops the rubber ball)?
2	John:	The energy of the ball is consumed.
3	Paul:	Yes (not evaluating). Why is there energy loss?
4	Mike:	For instance, air friction. Every time it goes up and down it affects it… its movement. (Students are putting their hands up)
5	Paul:	Yes (not evaluating). Jake?
6	Jake:	More energy goes to the floor.
7	Paul:	And in what form does it go to the floor? Richard?
8	Richard:	As heat.
9	Paul:	As heat (repeating). And where else?
10	Michael:	To the sound. We can hear the sound.
11	Paul:	Does it make a sound (drops the ball). Yes…we can hear a sound. Other ideas?

12 John: Against gravitation.

13 Paul: Against gravitation you said. And what does the energy convert to?

14 George: To potential energy.

15 Paul: Yes (not evaluating). It goes up…yes, but why doesn't it reach the same level?

16 Jake: The energy converts to another form.

17 Paul: Paul: Yes (evaluating). The energy converts to another form. And you said for example to heat, and many other forms. But when we think that energy loss occurs…Well some goes to the sound. But the rest…where does it go to? What does it convert to? Well, it has been said already… Richard?

18 Richard: To heat.

19 Paul: Yes, to heat! Through the friction of air…the energy changes its form to heat when the particles of air collide with the ball. The ball hits the floor and some of the heat goes to the floor and some of the heat to the ball. The kinetic energy converts slowly to heat. And in natural processes there is always some energy loss in the form of heat. (Transcribed and translated by 1st author)

Comments: At the beginning of this episode, Paul listened to the students' ideas (turns 3, 5 & 7), repeating them with a non-evaluative tone to ensure that everyone hears the answers (turns 9, 11 & 13). The beginning of the episode is clearly dialogic and Paul's planned intervention was to elicit pupil views (Appendix A). After hearing the pupil responses, Paul reviewed their ideas (turn 17) before moving on and closing the dialogic interaction by foregrounding the scientific view with authoritative teacher-talk (turn 19).

When asked about planning and implementing the lessons in the reflective feedback session Paul explained:

> Paul: When I was making the more detailed lesson plan I recognized quite quickly that there was an opportunity for dialogic talk… and in general because… I've been thinking about these things more and more, they come more naturally.
>
> Facilitator: What do you think…If these things hadn't been brought up specifically, like you said, at this point in the normal pre-service curriculum…?
>
> Paul: (Interrupts)…We would not think about these matters. When we are talking in feedback sessions with tutor teachers there are some things that they bring up. Like, does the teacher make an effort… or does he or she manage to pay attention to the pupils. These are the options. But in this program there is more thinking about how this could actually happen…

The episode involved Paul collecting pupil ideas with a non-evaluative tone (hence dialogic approach), however, the pupil ideas were taken no further. The dialogic level of this interaction, therefore, is considered low as was the case with other student teacher attempts to integrated dialogic interactions. Nevertheless, Paul's comments and lesson plan support the belief that he intentionally aimed to implement a dialogic approach. In contrast to David, Paul also reviewed the key concepts as they emerged and emphasized the scientific perspective effectively to conclude the dialogic interaction.

Summary of the Lesson Plans and Lessons. The video analysis process involved the identification of possible dialogic episodes. These dialogic episodes were then confirmed by checking the lesson plans and reflective feedback sessions in terms of purpose and intentionality. As illustrated in Table 3, Paul as well as 6 other student teachers did intentionally plan and implement dialogic approaches. The episodes were usually the same as introduced in Paul's excerpt: the student teachers used non-evaluative feedback to collect ideas from several pupils, but deeper exploration of these views did not take place and pupil turns were rather short. Three of the student teachers, Maria, Mark and Susan, were unable to implement dialogic approaches at the level they had planned, although dialogic attempts were made, as illustrated with David's case, and no extended dialogic episodes occurred fulfilling the dialogic criteria of the CA, as Paul's case illustrates.

With reference to Table 3, as Lea participated in the program with the proviso of no video recording she is not included. George's lessons were unfortunately rescheduled several times due to cancellations by the teacher training school and consequently the video-recording of his lessons could not be realized. This was also the case with Maria's second lesson. David and Kevin joined the teaching program later than the other participants. They were introduced to the CA during the first reflective feedback session, thus they had no explicit communication plans for the first lesson.

Table 3 Number of dialogic episodes in lesson plans and lessons

	Lesson 1		Lesson 2	
Student teacher	Lesson plan	Lesson	Lesson plan	Lesson
Anthony	3	2	2	1
George	-	-	-	-
David	0*	1*	1	1
Kevin	0*	1*	4	2
Maria	2	0	-	-
Paul	3	2	1	1
Susan	3	0	1	0
Joanna	1	1	1	1
Mark	1	0	1	0
Melanie	1	1	1	1
Rosanna	2	1	2	0

*=CA not intentionally planned/implemented
-=not available due to rescheduling

Research Question 2: How did student teachers experience dialogic interaction and its implementation?

Collective Responses: Student Teacher Comments on the Video-Excerpts of David and Paul. During the initial program 2007-2008 some student teachers experienced difficulties when observing and commenting on peer teaching episodes. In response to this the video-clips of David and Paul were used in the introductory lessons of 2008-2009 from the video databank. The purpose was to map student teacher views on these clips before introducing and practicing the CA. George, for example, commented on Paul's video clip saying, "It started a bit shaky, but in the end everything was correct." By "a bit shaky" George presumably refers to Paul's non-evaluative responses when the pupil ideas were collected. At the same time Paul's firm closure was appreciated. The student teacher comments indicate no awareness of dialogic interaction (including David in the feedback session). Even though Paul's episode includes clear characteristics of a dialogic interaction, as shown earlier, initially the student teachers showed no appreciation of this feature. The pre-conceptions expressed here confirmed the major concerns of the student teachers as correctness and establishment of the lesson content.

Student Teacher Discussion of the Teaching Program and Dialogic Interaction. This section presents the major themes and subthemes with frequencies based on the group-interview data (Table 4). Group-interviews were used to provide an opportunity for the student teachers to build upon the comments of their peers in dialogic interaction. In this interactive context, memories can more easily be refreshed and fruitful insights into student perspectives and perceptions can be more readily obtained (Borko, Mayfield, Marion, Flexer, & Cumbo, 1997; Eybe & Schmidt, 2004). Using the principles of the data-driven thematic approach the main themes included in the table below were identified: Interesting features of the data were coded in systematic fashion and in stages collated into major themes and subthemes (Braun & Clarke, 2006, p. 87). Table 5 contains illustrative examples and data extracts for each subtheme. The subthemes are numerically ordered linking them with the following illustrative examples. For example George’s comment in rows 4 and 5 depicts his views about the challenges of developing with dialogic implementation.

Table 4 Themes and frequencies produced from group-interviews

Research question 2	Major theme	Subtheme	Frequency
How did student teachers experience dialogic interaction and its implementation?	Increased awareness(14)	1) Awareness of DI increased(6)	George(2), David(2), Kevin(1), Paul(1)
		2) Awareness of the effects of the DI increased (e.g., atmosphere)(3)	Anthony(1), Kevin(1), Maria(1)
		3) Awareness of different roles in CA increased(5)	Anthony(1), George(1), Joanna(1), Paul(2)
	Challenges to dialogic teaching(18)	4) Question of discipline(5)	George(3), Joanna(1), Maria(1)
		5) Question of time(4)	George(1), Joanna(2), Mark(1)
		6) Insufficient content knowledge(5)	Maria(2), David(1), Kevin(1), Lea(1)
		7) Insufficient pedagogical content knowledge(4)	Maria(1), George(2), Joanna(1)
Additional themes	Videos(16)	8) Videos were useful(11)	Anthony(1), David(1), Kevin(1), Maria(2), Mark(1), Melanie(2), Rosanna(1), Susan(2)
		9) More video-recorded lessons(5)	Joanna(2), Kevin(2), Susan(1)

CA= Communicative Approach DI=dialogic interaction
(x)=frequency

Table 5 Descriptions and examples of subthemes (No.= subtheme number)

No.	Description	Data extract
1	Student teacher indicates increased awareness of dialogic options at a general level	David: I found that this was very useful… and from this brief experience I can say that this kind of approach is something that is likely forgotten. The teaching is mainly lecturing. This tool feels like something that I'm going to keep in-mind while in-service.
2	Student teacher recognizes one or more features that dialogic interaction could have a positive influence. E.g. creating an open atmosphere in the classroom.	Maria: I've been thinking about many of these things discussed here also. But what Kevin said about interaction, about the communicative approaches… that they create a certain atmosphere. That kind of atmosphere affects other things too. Even though at times the dialogic phase doesn't take place, that kind of relaxed atmosphere occurs in other situations also. It might have a positive effect in general… it doesn't matter if the teaching is lecturing at some points… and it should be every now and then. But even in those situations the atmosphere for learning stays comfortable. I noticed that during the observations in the Teacher Training School. And when I paid attention to some teachers' styles I discovered that in those lessons where… there were more discussions… well, those parts went more smoothly.
3	Student teacher indicates increased awareness about the different roles with regard to CA e.g. dialogic interaction to collect pupil views and authoritative approach to introduce the science view.	Paul: Yes. I thought it was useful to think about the communicative approaches and what kind of talk belongs where. I've been thinking about these things in more than just the video-recorded lessons. I think this has even made my lessons more coherent. There has been some kind of structure in the background and I've been able to include more dialogic approaches in my teaching. The very first teaching sessions were mostly lecturing at the beginning of the autumn… but because I involved myself with this project, I've been able to vary my talk and recognize what kind of talk could be used in specific situations…
4	For instance, student teacher indicates concern dialogic approaches leading to disciplinary problems.	George: I really think that teachers turn to survival mode and other things… But firstly, about the talk or dialogues, we do not even discuss that much here during the pre-service period, and if you have taught for many years you will forget those small details and you will take the easiest way to survive from the lessons.
5	Student teacher indicates that implementing a dialogic approach takes too much time	George continues: And peer discussions could be sometimes frustrating, when you feel that the discourse doesn't proceed and you start to respond to your own questions and again one lesson is behind. Joanna: I don't know if it is really so, that if a teacher teaches dialogically, that it would in every case be slower than when the teacher is teaching by lecturing… is it always inevitable? [Lea: I'm sure it isn't.]
6	Student teacher indicates that one must have sufficient content knowledge to feel confident in engaging in dialogic discussions	Lea: I'm sure it isn't. When you think for example about Mr. James, who in my opinion can teach dialogically, and those lessons in my opinion are very good… It requires very in-depth subject knowledge…
7	For instance, the student teacher indicates that s/he has insufficient prior knowledge of pupils' misconceptions, in order to be able to guide dialogic discussions appropriately.	Joanna: I just discussed this in that small scale study, because at no phase of the pre-service period are you told what kind of prior knowledge pupils have. And you are also in trouble yourself when you try to discuss when necessary… And there might be questions you cannot answer… And for sure, some of those questions come up frequently every year… So if you have taught one or two times you could know how to answer. I was wondering if I would have felt the dialogic discourse easier, if I'd had some material or background reading where there were dialogues that possibly would emerge.
8	Student teacher indicates videos being useful in reflection or/and analysis	David: After the lesson you might think that there were a lot of discussions, but after seeing the video you might notice you merely had a dialogue with yourself.
9	Student teacher indicates the need for more videos. (Mostly related to their own teaching)	Susan: It would have been nice to see lessons right from the beginning and compare them to the later ones.

…= pause; […]=talks over or immediately after

Comments: Themes 1-3 address student teachers' increased awareness with regard to the CA. When they discussed dialogic teaching they usually referred to the dialogic approach, which we consider one practical application of the CA. Theme 1 was constructed from student teacher comments that did not specify features of the dialogic interaction, instead the student teachers just noted that their awareness about dialogic options, had increased. The most common effect was the dialogic approach creating a classroom climate where pupils have opportunities to discuss and pose questions themselves. Theme 3 addresses the issue highlighting the role of different approaches in science teaching, for example, that the dialogic approach does apply to every instance, thus the authoritative approach also has its place in science education.

Themes 4-6 on the challenges of dialogic teaching were as anticipated addressing relatively familiar issues of insufficient pedagogical and content knowledge. The reflections of theme 7 indicate how research could contribute to classroom interaction and how classroom interaction requires a higher level of understanding. This kind of reflection could be seen to relate to pedagogical content knowledge (Abell, 2007; Shulman, 1986) and misconceptions, for instance, could be effective stimulants to engage pupils in challenging their own views if addressed purposefully.

The frequencies reveal that seven student teachers indicated increased awareness of communicative options, particularly dialogic approaches. With regard to the major theme *challenges*, Mark also contributed to the discussion. Susan and Rosanna did not comment directly on the major themes, although they did mention the usefulness of videos, the additional theme most frequently identified.

Discussion

The aim of the study was to examine science student teachers' physics lessons during their initial field experience and explore student teacher experiences when planning and implementing dialogic approaches. Lesson plans, lessons and reflective feedback sessions revealed that student teachers are able to challenge the traditional forms of teaching by including untypical (Mercer et al., 2009) dialogic approaches in their field practice. The additional group-interviews shed light on these experiences, highlighting the positive influence of the dialogic teaching program on student teachers' awareness of teacher-talk (themes 1-3). The student teacher perceptions prior to the program proved to focus firmly on content specific features rather than on the interaction between teacher and pupils. Within the program, videos were acknowledged to be significant agents when addressing different communicative aspects (themes 8 & 9).

David implemented a dialogic approach without any prior knowledge of the CA. His lack of awareness or purposefulness in using dialogic talk was apparent in his lesson plan and reflection, as well as in the lesson video. Whereas David's lesson mostly resembled traditional lecturing, Paul intentionally varied his classroom communications, evidenced in his planning, practice and reflection. The fact that not every student teacher was able to implement dialogic approaches in practice, regardless of their planned intentions, signals how challenging it is for student teachers to silence the authoritative voice of science, and to mediate dialogic interactions, especially during whole class discussions (Scott, Ametller, Mortimer, & Emberton, 2009). The implementation of dialogic approaches was mostly limited to the collection of pupil ideas rather than further exploration of these ideas. This may well indicate that student teachers lack confidence in their level of content knowledge (theme 6), an issue in-service teachers struggle with too (Childs & McNicholl, 2007; Colucci-Gray & Fraser, 2008). The student teachers also frequently brought up other reasons as to why dialogic approaches were not adopted with discipline and timing presented as the most important factors (themes 4 & 5). This conflict was voiced by George, who indicated an increased awareness of the CA on a general level and yet was also very skeptical of the challenges of implementing dialogic approaches in-service. Paul did not share this skepticism, however, possibly because his positive experiences and successful dialogic episodes inspired him with the confidence that dialogic interaction in future classes was attainable.

In relation to pedagogical challenges (themes 4 & 5), Kagan (1992) argues that before student teachers can adopt new insights into their teaching, their classroom management skills should be already established. Our findings agree instead with Grossman (1992), who stresses that if student teachers are supposed to go beyond the technical aspects of teaching and question their practice, they should be guided towards doing so:

> If our goal is not helping prospective teachers attain an immediate mastery of classroom routines, but preparing prospective teachers to ask worthwhile questions of their teaching, to continue to learn from their practice, to adopt innovative models of instruction, and to face the dimensions of classroom teaching, then we must place our emphasis elsewhere. (p. 176)

The results of this study indeed indicate that although student teachers are concerned about discipline and time, they are capable of challenging traditional forms of classroom interaction during their pre-service in both theory and practice. Nevertheless, as these findings indicate, for student teachers to successfully adopt innovative teaching methods, a significant amount of support is required.

The interview data reveal that although the main concerns of student teachers remain lesson content and discipline, another dimension to their views on teaching and learning had developed. The notion of dialogic interaction was shared with the student teachers as an important part of the broader Communicative Approach (Mortimer & Scott, 2003). The student teachers considered this approach useful in lesson planning and execution, as well as a useful tool in the analysis of videoed lessons. This finding relates to the most frequently identified additional themes 8 and 9 which confirm the role of videos as an essential and influential element in the intervention program. The student teachers reported that in addition to watching the videos, the reflections paying attention to specific features such as questioning and communicative options, for example, were extremely constructive. In relation to the limitation acknowledged before, surprisingly, also the student teachers wanted even more lessons to be filmed, a striking change from the beginning of the program. It may be that as a result of the program, the student teachers adopted a more analytical approach to their teaching. These findings suggest that this program which sought to dialogically share a new communicative approach formed a gestalt forum within which the student teachers could collaboratively share their views. This style of intervention may be particularly relevant if teachers feel insecure about adopting new methods of teaching (Meirink, Meijer, & Verloop, 2007). This program cannot, however, be considered as completely independent from its context, as indicated by the tutor teacher's comments and Paul's references to other external influences on the lesson content and execution.

Implications

This project has reinforced our prior assumptions that student teachers have difficulties understanding broader educational theories and their relevance in everyday teaching. Sociocultural aspects of teaching and learning are included in the curriculum but dialogic teaching and its practical applications are rarely highlighted, detailed, and practiced during field practice. On the basis of this study, the following suggestions aim to address this discrepancy:

- Instead of extensive time spent on broader educational theories about classroom interaction, student teachers should be introduced to specific scholarly descriptions of teacher-talk (such as the CA and IRF-sequence), in order to make different approaches explicit;
- Scholarly descriptions of teacher-talk should be used to train student teachers thoroughly with videos before using them in planning, real time observations, analysis and reflection;
- Overview figures (see figure 1) of lessons could be powerful tools to structure constructive feedback for teachers (2nd Author et al., 2006);
- Although videos are powerful stimulants to trigger reflections (O’Brien, 1993) they should be used with an analytical tool, such as the CA offers, to prevent irrelevant self-critical focus on secondary features of student teacher behavior (Levin, Hammer, & Coffey, 2009);
- Teachers should be provided with material including exemplary dialogic discussions and some general/specific hints (e.g. possibly emerging misconceptions) for planning and implementing these approaches. Furthermore, teachers should be provided with information about how to deal with emerging understandings in order to engage in educationally-purposeful extended dialogues (a limitation also noted within this study).

The prior notions of the student teachers made more visible in this study should be examined more extensively in forthcoming studies. Furthermore the inductive and practical approach to sociocultural theory of teaching and learning introduced in this paper could be continued as a part in-service practice. The threat does exist that real school culture could lead to regression; however, some teachers working independently in their classes have demonstrated the ability to continue professional development when well-prepared for reform (Franke, Carpenter, Levi, & Fennema, 2001). In Franke et al.'s study, teachers kept pupil thinking in the center when it came to their beliefs and practice about teaching and learning. As the student teachers in this study were profoundly concerned about classroom control, we hope that they will see talk as a tool for learning in the future. This issue will be examined in a longitudinal study involving some of the participants of the program when working as in-service science teachers.

Despite the previously listed procedures intended to maintain the objectivity of this study, as the first author led the intervention teaching program (necessary for the project) subjectivity within our research (Peshkin, 1988) is to some degree inevitable. Nevertheless, we still regard the findings of this study to have identified interesting issues, contributing valuable topics for further research within this area. Finally, we suggest that the topic and the content of the intervention program introduced in this paper could contribute to the professional development of all teachers not science teachers alone.

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Appendix A

David's and Paul's Lesson Plans

David: Lesson plan Tue 4.12.2007, Mrs. Hill, Secondary school's electric course

Structure

1. Introduction (of David) (5min)
2. Check homework (10min) (workbook, p.73, task 9 and textbook p.213, tasks 4 & 5) (Note: Data extract)
3. Theory (15min)
4. Experimental group work 1 (15min) *Notice proper explanations and reviewing (End of first lesson/Recess)*
5. Experimental group work 2 (15min)
6. Demonstration (20min)
7. ~~Experimental group work 3 (10min)~~ *skip if necessary*
8. Tasks (workbook p.81 tasks 1 & 3)

Theory

- magnet has north- and south pole
- similar poles reject each other and different poles attract each other
- magnet creates a magnet field
- this field can be modeled with field vectors
- magnets and magnetic matters interact via magnetic field
- For example Earth has a magnetic field that protects us from harmful particles coming from the Sun
- Magnetizing means that for instance iron nail is turned to permanent magnet by using another

Experimental group works and demonstrations

1. Experimental group work 1: Workbook p.74, task 1
2. Experimental group work 2: Workbook p.75, task 2
3. Demonstration: Workbook p.77, task 4
4. Experimental group work 3: Workbook p.79, task 5

Paul: Lesson plan Wed 12.12.2007, Mr. James, Upper Secondary Course nr.2, duration 9:50-11:25

Topic	Purpose	Implementation	Communicative approach
- Checking of the homework - A brief introduction	- Review the content of the previous lesson	- Pupils present their tasks in the front - Discussions about tasks and problems	Teacher presentation (NI/A) and authoritative discussion (I/A)
- Teaching new topic: Entropy	- Teach the concept of entropy	- Discussions about everyday phenomena involving entropy - Figure out together what entropy is	Dialogic discussion (I/D) Teacher presentation (NI/A)
- Demonstration	- Illustrate the previous	- A drop of color ingredient spreads to a water tank - Discuss about phenomena	Dialogic discussion (I/D) and teacher presentation (NI/A)
- Teaching new topic: energy conversion and the third law of thermodynamics	- Teach the concept of the energy conversion and the third law of thermodynamics	- Demonstration with a rubber ball to initiate thoughts - Figure out the new topics with the assistance from the pupils	Dialogic discussion (I/D) (Note: Data extract) and teacher presentation (NI/A)
- Energy in society (2nd half of the double lesson, not in the lesson figure)	- To get pupils motivated to seek the information	- Getting familiar with greenhouse effect via slideshow - A group work - Reviewing together	Teacher presentation (NI/A) Peer discussions Dialogic discussions (I/D)

III

ENRICHING PRIMARY STUDENT TEACHERS' CONCEPTIONS ABOUT SCIENCE TEACHING: TOWARDS DIALOGIC INQUIRY-BASED TEACHING

By

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Enriching primary student teachers' conceptions about science teaching: Towards dialogic inquiry-based teaching

Abstract

Inquiry-based teaching has been at the heart of science education since it was first outlined in national standards over a decade ago. The general idea behind the inquiry guidelines is that pupils would adopt ways of conducting science, in addition to conceptually learning, thus attaining also the epistemological dimension of science. Although curricula are based on these ideas of inquiry, all too often authentic inquiry is hindered by overly authoritative approaches and teacher directions. To avoid this, the communicational ways in which teachers can encourage pupil reasoning during different phases of inquiry should be explicitly addressed. This paper addresses this gap by introducing a dialogic inquiry-based approach to science education. This approach combines the principles of inquiry and dialogic teaching. Based on this framework we investigated a number of primary student teachers' (n=28) conceptualisations of science teaching and evaluated to what extent dialogic inquiry-based teaching informed these conceptualisations. Analysis revealed that dialogicality was not present in student teacher pre-conceptions, their pre-conceptions rather focused on traditional practices related to science teaching. The learning trajectories created for six cases, however, indicate an increased awareness of inquiry-based teaching including the dialogic aspect over the duration of the course.

Introduction

In the present study we introduce the results from an investigation into primary student teachers' conceptualisations of science teaching. Our study focuses on the development of these conceptualisations during a science education course for primary student teachers. This paper presents how primary student teachers conceptualisations of teaching science developed during a course focusing on inquiry-based science teaching. The main aim of the course is that our primary student teachers may consider learning processes in science more deeply, not based only on their own scientific knowledge. Our science education course introduces and is based on inquiry-based teaching, which includes the increasingly popular concept of discussions in research within classroom interaction: dialogic teaching (e.g. Alexander, 2004; Nystrand, Gamoran, Kachur, & Prendergast, 1997). In addition to, and related to dialogic teaching, we also present scholarly descriptions of teacher-talk characterising communicative approaches with an emphasis on the dialogic dimension of science teaching.

Inquiry-based approaches have been increasingly popular in science teaching and professional development programmes (e.g. Akerson & Hanuscin, 2007; Luera & Otto, 2005) especially following the outlining of these approaches in the U.S. National Science Educational Standards in 1996 (National Research Council, 1996). One limitation of these programmes is that they tend to neglect the dialogic aspect of inquiry-based science teaching. These programmes tend to focus on other aspects such as designing appropriate lessons, adopting effective teaching methods, following particular instructional activities, and evaluating pupil learning. In addition, professional development programmes are often based upon lectures and the transmission of knowledge and lack integration into instruction (Abell, 2000), thus failing to access student teachers' pre-existing needs for professional development (Chval, Abell, Pareja, Musikul, & Ritzka, 2008). Although the guidelines of inquiry-based approaches are in many ways related to dialogic teaching, the descriptions involved (e.g. guider or co-inquirer) are often uninformative when it comes to deeper understanding of complex interactions going on in inquiry-based science classrooms (Oliveira, 2009). We address this gap by introducing the results of a teaching programme that introduces primary student teachers with inquiry-based teaching and highlights the different communicative approaches and their role in scientific inquiry.

Theoretical framework

This chapter introduces the three main concepts drawn upon for our theoretical framework: inquiry-based teaching, dialogic teaching and the communicative approach. The critical consideration of these notions lays the foundation for our exemplary model of dialogic inquiry-based teaching.

Inquiry-based teaching

The basic principle behind inquiry-based teaching is that this approach can more effectively prepare pupils for future challenges and support a better understanding of science and conducting science in general. According to Akkus, Gunel and Hand (2007) study, pupils who participated in a course in which inquiry-based teaching was applied achieved better learning outcomes than in traditional courses. The course included pupils planning and selecting the problems to be inquired into more deeply. Other studies also support these results (e.g. Minner, Levy, & Century, 2010). A controversial argument related to inquiry-based teaching from Abrahams and Millar (2008) states that doing experiments alone does not lead to better learning outcomes. This problem is often apparent in inquiry-based science classes in which experiments conducted by pupils are overemphasized (Saari & Sormunen, 2007). In order to support pupils' learning teachers should be more aware of different phases and aspects of inquiry-based teaching.

In general terms, the essential features of classroom inquiry have been described as follows:

- Learners are engaged by scientifically oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding
- Learners communicate and justify their proposed explanations. (National Research Council, 2000. p.25)

It can be summarized that according to inquiry-based science teaching and learning, it is important for students to consider their own ideas and arguments alongside experimental exercises. According to this characterization, communication and students' pre-conceptions are both important features in inquiry-based teaching. Furthermore, problem-based approach, making hypotheses and finally strengthening the scientific view should be applied during inquiries (Linn, Davis, & Bell, 2004). In addition to the previous guidelines experimental methods are highlighted in the current Finnish comprehensive curriculum (FNBE, 2004; Pehkonen, Ahtee, & Lavonen, 2007). Although, the principles of inquiry have become increasingly popular in science classrooms, with a student recognized as an "active inquirer" and the teacher as a e.g. "co-inquirer", inquiry-based science methods remain often vaguely described and applied (Oliveira, 2010, p. 432).

Dialogic teaching

According to Alexander (2004), dialogic teaching should seek to extend pupil reasoning and understanding. The activation of pupils is also essential in dialogic teaching. The key characteristics of dialogic teaching are briefly described as:

- collective: teacher and pupils jointly participate in the learning as a group or as a class;
- reciprocal: teacher and pupils listen to each other, share ideas and consider alternative views;
- supportive: pupils can present their ideas freely without fear of being incorrect;
- cumulative: teacher and pupils develop their ideas, jointly constructing knowledge;
- purposeful: the teacher plans and guides the discourse paying attention to educational goals in addition to the above.

Although some other studies present alternative student-centred approaches (e.g. Peters, 2010), the concern over over-authoritativeness remains justified worldwide. Recent observation studies in the UK (Mercer, Dawes, & Staarman, 2009) have revealed that dialogic practices are more than uncommon in science lessons. Dialogic teaching takes pupil ideas into account without an evaluative tone. Pupils are encouraged to participate, and ideas are discussed and respected. This lack of the dialogic aspect is a concern when thinking about the different phases of inquiry-based teaching: Teachers either take too much control of the inquiries or do not guide pupils at all, which also should not be the case. It has been discussed that pupils are able to adopt discursive strategies that are beneficial for higher levels of learning, if they are purposefully enabled to do so (Rojas-Drummond & Mercer, 2003). In other words, although the teacher is essential when moving from simple everyday explanations to more disciplined and scientific ones (Roth, 2005), s/he should not do all the thinking for pupils. Indeed, there is a concern over the openness of inquiries, as too often they proceed in a way predetermined manner in which pupils work towards the desired outcome (Sadeh & Zion, 2009).

Dialogic teaching includes important features for motivation and deeper learning. In our opinion, however, it fails to sufficiently stress the fact that science teaching should also include an authoritative aspect. The gap between the pre-existing views of pupils and the scientific view is often too big to be addressed using the dialogic aspect alone. Having said this, the concept of the communicative approach (Mortimer & Scott, 2003) offers a unique perspective to describe classroom interaction considering both dialogic and authoritative aspects.

The communicative approach

Although inquiry-based teaching can provide a very suitable context for different communications, the danger remains that inquiry-based teaching is not applied as it is intended. Too often the teacher may be excessively concerned with the correct content during inquiries and does not yield the scientific authority. In order to avoid these shortcomings, teachers should be aware of different communicative approaches (Mortimer & Scott, 2003), in particular the dialogic dimension that takes into account and works with pupil views without an evaluative tone

Mortimer and Scott's framework for describing classroom discourse consists of four categories generated from the combination of two dimensions: interactive/non-interactive and authoritative/dialogic. *Interactive* talk allows pupils to participate, whereas *non-interactive* talk is of a lecture type. Whereas the *dialogic approach* takes account of diverging ideas, the *authoritative approach* focuses on a specific point of view, usually the one of science, controlled by the teacher:

- In the *interactive authoritative* approach, in the question-answer routine, pupil responses are often evaluated and the teacher omits diverging ideas. The authoritative approach focuses on the scientific point of view.
- In contrast, the *interactive dialogic* approach explores and exploits pupil ideas (e.g. everyday views), and has no evaluative aspect. Thus, the dialogic approach, in Mortimer and Scott's categorisation, is enacted when the teacher is not trying to achieve a specific point of view. Rather, the teacher tries to elicit the pupils' points of view and works with these contrasting views.
- In the *non-interactive authoritative* approach, the teacher presents the scientific content by lecturing and no contrasting points of view are taken into account.
- In the *non-interactive dialogic* approach, the teacher works with contrasting points of view, for example with pupil everyday views, and works towards the scientific view. In this approach, even though the teacher uses a lecture format, diverging ideas are discussed. Thus, teacher-talk is dialogic in nature.

Scott and Ametller (2007) stress that meaningful science teaching should include both dialogic and authoritative aspects. For instance, if discussions are 'opened up' by a dialogic approach and pupils are given the opportunity to work with different ideas, at some point discussions should also be 'closed down' via an authoritative approach. The 'closing down'-phase could be very important, for instance, when making clear what the differences between pupils' everyday views and the scientific view are. We included these two phases in our exemplary model of inquiry-based teaching, which we shall present next.

Dialogic inquiry-based teaching: An approach to examine inquiry-based teaching

Building on the critical overview of inquiry-based teaching, communicative approach and dialogic teaching, it is important to illustrate how these concepts can interplay with each other when thinking about both theoretical and practical purposes. In an attempt to meet the challenge of implementing inquiry-based teaching with dialogical aspects and educational goals, we have developed an exemplary process model to take these different aspects into account (Table 1). This process model can be considered the result of combining different educational theories and concepts. The model could be also considered as a theory-based planning tool for dialogic inquiry-based teaching. Whilst our understanding of dialogic inquiry-based teaching, is not directly the same as Wells' (1999) 'dialogic inquiry', our exemplary model of dialogic inquiry-based teaching aims to highlight and bring forth the same characteristics emphasised by dialogic inquiry: the dialogic and social dimensions of teaching and learning.

Table 1. Phases of the dialogic inquiry-based teaching.

	Inquiry-based teaching Linn, Davis & Bell (2004)	**Communicative approach** Mortimer & Scott (2003); Scott & Ametller (2007)	**Dialogic teaching** Alexander (2004)
Initiation phase	-Problem-based approach -Considering pupils' pre-conceptions	-Opening up phase: -Dialogic and interactive -Dialogic and non-interactive	Supportive Reciprocal Collective Cumulative Purposeful
Inquiry phase	-Planning -Making hypotheses -Collecting information -Executing the inquiry	(- Weight is on the pupil-pupil interaction)	Collective Cumulative Purposeful
Reviewing phase	-Comparing the results to the scientific view -Creating models -Argumentation -Reinforcing the scientific view	-Closing down phase: -Dialogic and non-interactive -Authoritative and interactive/non-interactive	Supportive Reciprocal Collective Cumulative Purposeful

The *initiation-phase* includes probing pupil pre-conceptions, and even though pre-conceptions at this point could be considered as misconceptions, pupils should be given the opportunity to express them. Using a problem-based approach the teacher could reveal these (mis)conceptions by employing a dialogic approach and opening up problems requiring inquiry. At a later stage the views can be reflected on again against the results of the executed inquiry.

The actual *inquiry-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 of a tutor than director, in this way creating the ground for meaningful planning and inquiries. Although pupils are expected to do the thinking, the teacher could still raise questions that guide pupils work and thinking further. We emphasise that in this phase the teacher should especially encourage pupil-pupil interaction. Despite doing this, the likely danger exists that the group dynamics lead to interactions that could be considered as authoritative leaving no place for authentic inquiries. To address this threat in peer discussions, scholars have introduced the concept of exploratory talk reflecting the characteristics of Alexander's dialogic teaching (Mercer, 1995; Mercer & Littleton, 2007; Littleton & Mercer, 2009). Briefly, exploratory talk includes pupils engaging critically, yet constructively with each others' ideas. However, since our focus is firstly on developing teacher-pupil interactions, we shall not discuss these matters more extensively in this paper.

The *reviewing-phase* is essential when it comes to achieving educational goals. Although this phase uses more authoritative communication, the pre- and misconceptions should be reviewed against the scientific results and theories in order to make explicit the connections between views (e.g. everyday views and the science view) and possible lacks in previous thinking. Since different ideas are still considered, the dialogic approach is also present. The authoritative approach should still be implemented when making the final conclusions about the content and also about the procedure itself. All in all, when problems are opened up (dialogic approach) they should also be closed down (authoritative approach). This is the key to meaningful science learning which consists of both aspects of communication (Scott & Ametller, 2007).

The study objectives

Previous studies about science professional development programmes provide extensive insights into inquiry-based teaching. However, one crucial limitation of these programmes is that they tend to forget the social aspect of inquiry-based science teaching (Oliveira, 2009 & 2010) and overlook student teachers' pre-existing needs for their development (Chval, Abell, Pareja, Musikul, & Ritzka, 2008). To address these limitations, this study aims to provide insights into primary student teachers pre-conceptions of good science teaching, and to examine how primary student teachers developed their understandings of the social aspects by introducing the ideas of dialogic inquiry-based teaching during a science education course. In other words, this paper seeks to address the following questions:

- What are student teachers' ideas of science teaching?
- How did a course on dialogic inquiry-based teaching affect student teachers' conceptualisations of science teaching?

Methodology

Science course description and participants

At a university in Finland the science education course for primary student teachers is 9 credits out of the total Master's degree which is 300 credits (ETCS). The course extends for one academic year beginning in September. The core of the course is a study project which the student teachers prepare in groups. Each group develops a teaching-learning sequence on one science topic. The project includes the content analysis, exploring pupils' ideas on the topic, finding, selecting or creating the most appropriate presentations and teaching strategies, and making a plan for a teaching-learning sequence of several lessons. Most of the teaching of the course (lectures, group work, assignments, etc.) supports the study project. Since we believe that classroom communication, which enhances the quality of cognitive knowledge, is essential for the purposeful learning processes and professional development, the course includes tutoring towards more dialogic teaching. The timetable of the science education course is shown in Table 2. The table includes the general objectives for the lecturer to execute and to develop the course, yet information about the different activities for student teachers is also provided.

In total, 28 primary student teachers took part in the course about dialogic inquiry-based teaching. The aims of the course were that:

- Student teachers would become aware of their understanding of science teaching and science content knowledge.
- Student teachers would learn project-work in collaborative settings: to strengthen their knowledge about inquiry-based teaching and content.
- Student teachers would plan an inquiry-based learning environment for pupils.

The general aim of the course was that student teachers would shift their focus from concern with their own subject content knowledge to the learning processes and dialogic requirements. The course was supervised by the 2nd author of this paper, a lecturer in the Department of Teacher Education where the student teachers conduct their pedagogical studies and teacher training.

Table 2. Timetable for executing and developing the science education course.

Stage	Task	Month/ year
1. Development of the teaching sequences	Meeting primary student-teachers. Instructing dialogic teaching strategies to students. Practices.	09/09-12/09
	Implementation of the teaching sequences, classroom observation and analysis during classes in training school.	01/10-02/10
2. Development of the teacher training material	Discussion with students and teachers about their experiences, dialogic inquiry strategies and communication with other students and teachers.	01/10-05/10
	Development of the teacher training course materials in collaboration with primary student-teachers. Students produce Teaching Learning Sequences (TLS) related to global warming and dialogic teaching.	01/10-05/10
3. Assessment and further development of the teacher training course	Running of the pre-service teacher training course (including some classroom observation and analysis). TLS evaluations during teacher training period.	01/10-02/10
	Students finish their report. Analysis of the course and its results. Implementation of the strategies for the schools by the students participating in the course.	03/10-05/10
	Discussion on the course structure, content and methods (teacher experiences and self, peer and researcher assessment)	05/10

Data collection and analysis

The data consists of three different inquiries with the student teachers: pre-conceptions (n=28), mid-interviews (n=6), and post-interviews (n=6). Whereas the pre-conceptions were mapped from all of participants, the mid- and post-interviews were collected from one student teacher group consisting of six student teachers, who were selected for longitudinal examination. All names are pseudonyms in order to guarantee the absolute anonymity of the participants. The participants provided permission to present the data related to this project.

The pre-conceptions were collected at the beginning of the academic year 2009 (September) during the first meeting of the course. The aim was to map student teachers pre-conceptions about good science teaching. The student teachers were asked to write an essay by continuing the following sentence "I think good science teaching should be taught…". They had 20 minutes to write the essay. The informal term "good" was used in order to provoke what student teachers themselves think would stand for appropriate teaching of science. The data-driven analysis included categorising the student teacher conceptualisations. Following careful readings of the student teacher essays we identified certain keywords to describe the student teacher ideas and on this basis three main categories were created: teaching methods, pedagogy, and communication. The formation of the keyword categories included the careful interpretation of the content of the student essays, thus interpretations were carefully discussed with several researchers. For instance, if a student teacher only mentioned experiments without taking pupil pre-conceptions into account, pupils as active participants or problem-based learning, the identified keyword was experimentation rather than inquiry-based teaching.

The mid-interview with one student teacher group was held in December (mid-course). This interview aimed to inquire into the ongoing development of student teacher conceptualisations of science teaching, inquiry-based teaching and dialogic teaching. All of the participants in this group were females as is common in Finnish primary teacher education. The interview was tested before the actual data collection and some adjustments were made in order to establish coherence. The interview included background questions, instructions for drawing a concept map and the actual interview. The open-ended interview initiated with a question similar to the pre-conception inquiry and continued with questions about inquiry-based teaching and dialogic teaching (APPENDIX 1).

The post-interview (APPENDIX 2) included semi-constructed individual interviews. The interviews (30 min) inquired into the student teachers conceptions about dialogic inquiry-based teaching and their willingness to use it in service. In the mid- and post-interviews the data was categorised more from a theoretical, than a data-driven, approach. Categories included concepts of the communicative approach and concepts related to inquiry-based teaching (e.g. pre-conceptions of pupils, problem-based approach, making hypotheses). The notion of dialogic relates to both the communicative approach and inquiry-based teaching. After the categorisation, the data was interpreted based on the exemplary model of dialogic inquiry-based teaching presented earlier. The model was also used in the analysis of the student teacher pre-conceptions and creation of learning profiles for the six cases. In all phases the data was analysed by applying researcher triangulation (Cohen, Manion, & Morrison, 2007). The categorisations and interpretations were discussed between the researchers and revised until satisfactory agreement was established.

The creation of the learning profiles

The level of understanding for each of the six student teachers were analyzed with regard to the concepts of interactive inquiry-based teaching at each of the different phases (pre, mid and post). The learning profiles below describe five possible levels for the learning outcomes. The levels were created on the basis of the data in order to describe the conceptual changes in as much detail as possible.

We analysed interaction and inquiry aspects separately as there were differences in student teachers' understanding of these concepts. Zero-level indicates that a student teacher did not mention anything related to inquiry-based teaching or interaction in teaching. The highest, fifth, level indicates that a student teacher has a good theoretical background about inquiry-based teaching and interaction in teaching. The criteria for evaluating the levels of understanding are presented in Tables 3 and 4. The evaluation criteria are based on the theories presented in Table 1. In table 3 the criteria of inquiry-based teaching is complemented with communicative approach (see level 5). In table 4 instead, the communicative approach and dialogic teaching have been merged to form a criteria for evaluating the interaction in classrooms.

Table 3. Evaluation criteria for creating the learning profiles in inquiry-based teaching.

Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Concepts related to inquiry-based teaching are not present in comments	Some concepts are present in comments E.g: -experiment-ations -pupil-oriented approach	Pre-conceptions are considered	Pre-conceptions are considered	Pre-conceptions are considered	Pre-conceptions are considered
		Planning	Planning	Planning	Planning
		Inquiring	Inquiring	Inquiring	Inquiring
			Problem-based approach	Problem-based approach	Problem-based approach
				Hypotheses	Hypotheses
				Considered as inquiry	Considered as inquiry
				Modelling is present in comments	Modelling is consistent
					Different phases of communica-tivity are present in the process of inquiry-based teaching

Table 4. Criteria for evaluating classroom interaction. The criteria are combined from the communicative approach and dialogic teaching (collectivity, reciprocality, supportivity, cumulativity and purposefulness).

Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Concepts related to interaction are not mentioned	Dialogicality is assimilated with dialogue	Two or three dialogic criteria are mentioned	Four dialogic criteria are mentioned	All criteria are mentioned	All criteria is mentioned
			Opening phase is understood	Opening phase is understood	Opening phase is understood
				Closing phase is mentioned	Closing phase is understood
				Communicativity is partly integrated with inquiry-based teaching	Communica-tivity is integrated with inquiry-based learning
					The authoritative part of the inquiry is understood

Results

Before presenting examples of learning profiles, which indicate the changes in perception, we briefly shed light on the initial status of the student teacher pre-conceptions. The percentages of the categories and examples of the most frequent keywords are provided.

Overview of the pre-conceptions of good science teaching

Three main categories created from the keywords which were identified from student teacher pre-conceptions: Teaching methods (51% of all keywords belonged to this category), pedagogy (37%) and communication (12%), (Table 5). The keywords were applied as properly as possible once again applying the researcher triangulation (Cohen, Manion, & Morrison, 2007) in order to establish validity in our judgements.

Teaching methods were predominantly considered in the student teacher pre-conceptions of science teaching. The pre-conceptions indicated that the everyday information does not provide direction for inquiry-based science teaching. According to the student teacher pre-conceptions, science teaching should include outdoor education (frequency 15), research as lab work (14), illustration (12) and inquiry (10). Those components seem to form the traditional authoritative approach to science teaching and do not include modelling of the scientific study process. Below is a data extract that concerns *outdoor education*.

> "Science should be taught by familiarisation with nature for real, for example visiting forests, and not just looking at pictures of nature" - Nelli

Table 5. Pre-conceptions of science teaching: Categories, dominant key words and frequencies.

Category	% of key words	Dominant key words	Frequency
Teaching methods	51	Outdoor education	15
		Researching as lab work	14
		Illustrations	12
		Inquiry	10
Pedagogy	37	Practicality	12
		Pupils' experiences	8
Communication	12	Discussions	6
		Group work	5

The student teachers' way of thinking concentrated on paying attention to pupils' own experiences and on dealing practically with phenomena. Even though the student teachers have studied pedagogy before the science course, the pedagogic thinking reflected relatively little consideration of pre-conceptions. The utilisation of pupils' own experiences indicates the ability of the student teachers to engage in pedagogic thinking, however, the pre-conceptions concentrated on teaching approaches which the student teachers experienced as pupils.

The second biggest (37% of keywords) category was pedagogy. This category includes topics related to teachers' intentional instructional decision-making. These are for example: use of different teaching methods, taking account of different learning and learners, and taking advantage of educational understandings. *Practicality* was the dominant keyword (12) in this category:

> "I think science should be taught as practically as possible, at least at primary level, and not only with abstract concepts" - Mika

The keywords related to communication formed the smallest category (12% of keywords). Two keywords dominated this category: *Discussions* (6) and *group work* (5):

> "In discussions pupils bring forth their own reasoning and conceptualisations" – Johanna
> "I think science should be taught by doing group work in small groups" - Joni

Overall when comparing the student teacher pre-conceptions with the cornerstones described in the introduction to the NRC (National Research Council, 2000, p. 25), inquiry-based teaching does not appear to be sufficiently present, although some elements, such as taking account pupils' pre-conceptions, are mentioned. A problem-based approach and generating hypotheses, however, do not extensively appear in the student teacher perceptions.

Overview of the learning profiles

We shall continue by using selective illustrations from the data in order to work within the space limitation of an article to exemplify and discuss our findings of the study as a whole. We shall first illustrate the learning profiles of all six student teachers that participated in the pre-mid-post investigations of this study. Following the overviews, we present the case of Anniina by introducing some of her comments followed by interpretations related to the creation of her learning profile. We selected Anniina to be our illustrative case, as extracts from her data effectively exemplify our criteria for inquiry-based teaching and interaction in teaching (Tables 3 & 4).

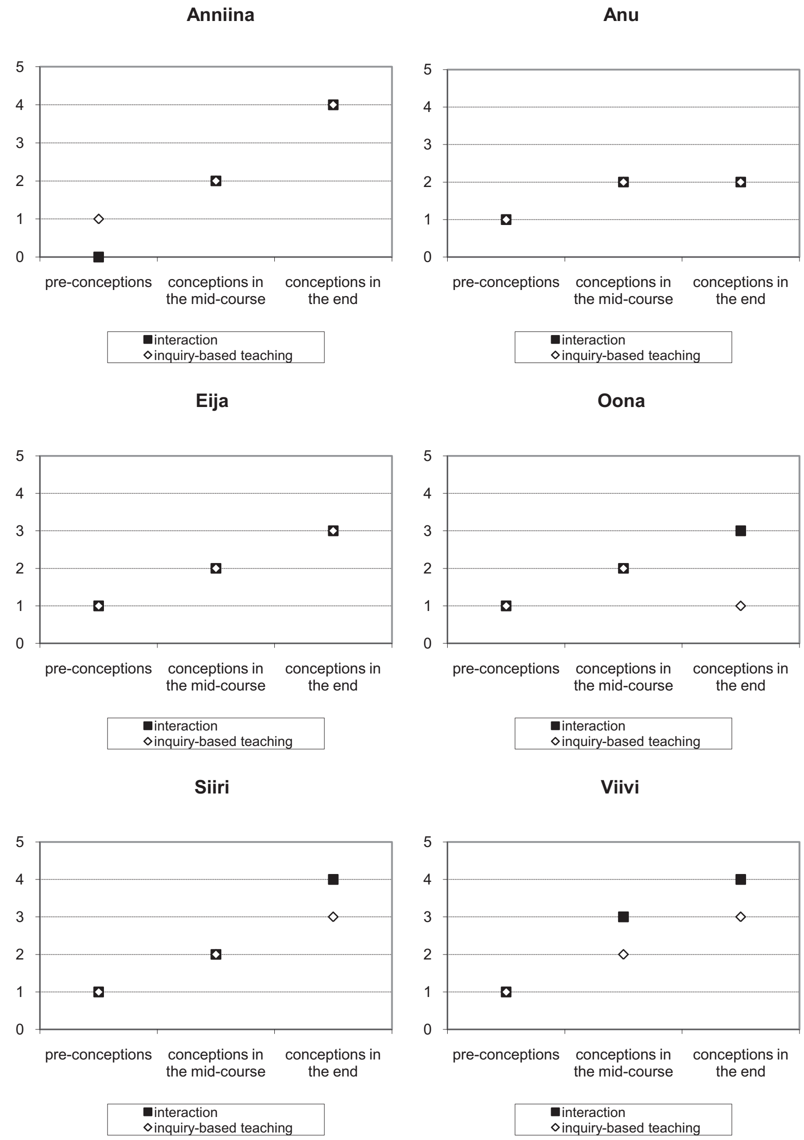

Figure 1. Overview of the learning profiles.

Figure 1 presents the learning profiles for each of the six student teachers with progression visible in four of the six cases. Anu and Oona indicate regression (or retention) when it comes to adopting the characteristics of good dialogic inquiry-based teaching. Anniina's learning profile indicates the greatest progress. Indeed, the examples of Anniina's data revealed some well developed ideas when it comes to dialogic inquiry-based teaching.

The case of Anniina

Table 6 presents the level of Anniina's pre-conceptions and conceptions about good science teaching at the beginning, in the middle and at the end of the course.

Pre-conceptions

Anniina had a pupil-centred view of science teaching at the beginning of the science course. Based on the excerpt (Table 6) from Anniina's essay and her phrase "experience-based", she was assigned level one according to our inquiry category. Anniina wanted to link theoretical knowledge with pupil experiences. Anniina also wrote that experimentation is something that is relevant for level one of inquiry, as the following extract indicates:

Table 6. Examples of evaluation criteria of Anniinas' profile excerpts and rationales for levels. Inq. = Inquiry and Int. = Interaction.

Phase	Criteria (x)=level	Excerpt	Rationale
Pre-conceptions	Inq.(1)	I think science should be taught on the basis of experience, it would be good to link theories to everyday experiences, which are something that can be surely found in science	Pupil-oriented approach
	Int.(0)	-	No indicators
Mid-course	Inq.(2)	… at least in the beginning the teacher must find out what pupils know about the topic already, to be able to figure out how to begin. And then somehow pupils can find out the things by themselves…	Pre-conceptions
		… of course you must give a lot of guidance and you can ask pupils for their ideas, but you must also have a sense of direction. And an idea from where and what kind of information you would want to seek.	Inquiry execution
	Int.(2)	…that you would listen also to pupil views and see were it leads to. That you would not like beforehand decide the way you teach.	Reciprocality Collectivity
		Then you discuss them together and make corrections. You would also have to listen to incorrect answers, which is just what is important	Supportivity Collectivity
Concep-tions at the end	Inq.(4)	…the teacher first finds out pupils' pre-conceptions and perhaps also mis-conceptions then based on those the inquiries begin…	Pre-conceptions
		…when making the hypotheses and experimental settings, even then one could think about the dialogicality, that pupils could themselves think through what to inquire into and how. Based on the pre-conceptions you could create a few hypotheses. In this way, pupils think beforehand what the results of the experiments could be [Essay]	Planning Execution Hypotheses
		Inquiry is based on the problems that arise during the inquiry …	Problem-based approach
		In a way a pupil does the thinking process that researchers have done when they have done their inquiries.	Inquiry-based approach as a flexible framework

		…That s/he understands it right from the beginning that what causes phenomena, and not just memorise them, understands why things happen and how things work. Questions might have emerged during discussions, which could be attached to a concept map. [Essay]	Indicators about modeling (coherent ideas not required yet)
	Int.(4)	Inquiry leans on the discussions and problems that emerge during them… …when making the hypotheses and experimental settings, even then one could think about the dialogicality, that pupils could themselves think through what to inquire into and how. You discuss with pupils (first in groups and at the end together)… Pre-experiences are important to find out… Teacher makes a list of pupils' views, even the wrong ones…[Essay]	Opening phase Collectivity Reciprocality
		…teacher first finds out pupils' pre-conceptions and perhaps also mis-conceptions then based on those begin the inquiries…	Supportivity
		The whole class assembles to check through the results of the experiments. Results are compared. The correctness of the hypotheses will be discussed, and if not correct, the mis-conceptions will be identified. Use of concept mapping. [Essay]	Cumulativity
		Teacher guides, yet not giving anything ready. Rather asks questions that gently direct pupil thinking towards the right path, or towards things you should discuss.	Purposefulness
		After completing the concept, map pupils understanding should be deepened. You could think of the reasons for observed phenomena during the experiments and in this phase the teacher could also explain things in more detail as s/he should have more knowledge about the topic.[Essay]	Closing phase

> "As a form of support, experiments could also be used in lessons, so that one could see with one's own eyes how things work"

Whilst Anniina states that through experiments pupils could see how theories work in practice, she does not mention planning the experiments or problem-based learning. Anniina also mentioned outdoor activities as part of meaningful science teaching. On the basis of these comments, she seems to have quite a traditional view of science teaching, layered with constructivist characteristics. Nevertheless, Anniina did not directly mention anything about taking pupils' pre-conceptions into consideration, i.e. to inquiry-based teaching, inquiry, or experiments were not mentioned. At the beginning of the course, therefore, we consider Anniina's level of interaction to be zero.

Mid course conceptions

In the middle of the science course, besides an individual interview, Anniina drew a concept map on good science teaching (Figure 2). Based on her concept map it could be argued that Anniina's thinking included characteristics of pupil-centred inquiry-based teaching because she considered

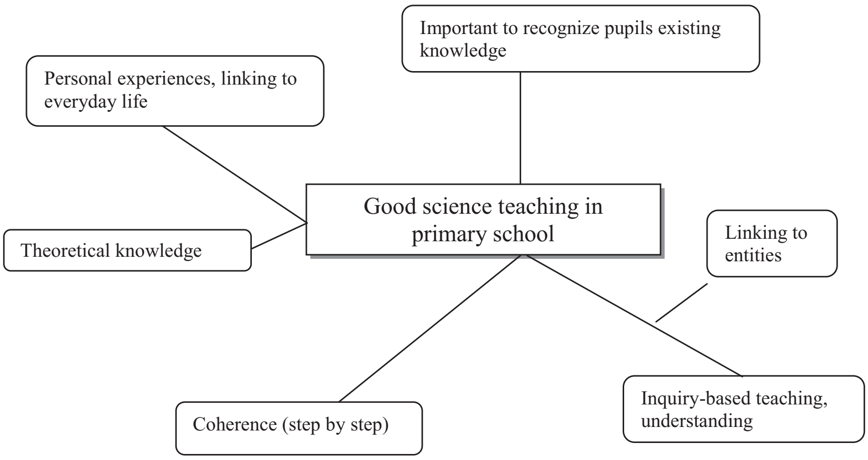

Figure 2. Anniina's concept map.

pre-conceptions as a basis for teaching. Inquiry-based teaching, understanding and pupil-centeredness were new concepts when compared to the mapped pre-conceptions on good science teaching.

In Anniina's opinion, good science teaching includes inquiry-based teaching and understanding (Table 6). Furthermore her map suggests that it would be good for teachers to be aware of the existing (pre-) knowledge of the pupils. This element was absent in Anniina's pre-conceptions.

During the mid-course interview Anniina mentioned the following features of good science teaching: inquiry-based teaching, pupil pre-conceptions, dialogic teaching, collective learning and understanding. At the beginning of the course Anniina did not mention anything related to interaction. During the mid-stage, Anniina commented that dialogic teaching is a good approach to consider, and she also emphasized many times that a teacher should take pupil pre-conceptions into account: "*at least at the beginning teacher must find out what pupils know about the topic…*" "*…of course you must give a lot of guidance…*" (see Table 6). Thus, Anniina highlighted the teacher role in controlling the direction of learning.

Moreover, Anniina associated dialogic teaching as mostly being listening to pupil ideas, as well as recognising the supportive and interactive nature of this approach as conceptualised by Alexander (2004) including *reciprocity*, supportivity and collectivity (Table 6). When thinking about our exemplary model, Anniina evidently has an idea of the opening phase of the inquiry-based teaching. Nevertheless, she did not mention the key characteristics according to Linn, Davis and Bell (2004): problem-based learning/approach and making hypotheses. When comparing previous remarks to pre-conceptions, we suggest that Anniina progressed during her studies with respect to both inquiry based learning (level 2) and interaction criteria (level 2).

End of course conceptions

At the end of the science course, Anniina once again brought up the importance of taking pupil pre-conceptions into account both at the beginning and at the end of the inquiry (Table 6). According to Anniina, the results of inquiries should be compared with pupil experiences and pre- and mis-conceptions. This relates to the cumulative learning of science and Anniina wrote in her essay that concept mapping with pupils includes the adding and deleting of mis-concepts and the addition of new concepts formulated during discussion. Authentic consideration of pupil views addresses the reciprocal nature of interactions. Dialogicality is integrated into her views on inquiry. However, Anniina still did not fully acknowledge the role of the authoritative approach during the closing phase because she wrote in her essay "*…it would be important that the concepts added to the (final) concept map are explicitly formulated from pupil ideas*". Due to the previous notions we consider that Anniina's understanding of interaction in science teaching developed to level four.

When considering the inquiry criteria, Anniina mentioned many aspects of the problem-based approach (Table 3 & 4). Thus her ideas of science teaching covered, for example, pupil pre-conceptions and as emerging from her comment, besides highlighting problem-based initiation for inquiries, the making hypotheses is also a new feature that can be identified (Table 6). Table 3 indicates that the process initiates as problem-based, and after mapping the pre-conceptions of pupils, proceeds to the planning phase in which preliminary hypotheses are discussed. Those viewpoints of science teaching and learning and also model thinking was visible in Anniina's ideas of science teaching at the end of the science course. We therefore suggest that Anniina achieved the level four of inquiry criteria. Evidently, Anniina has taken a step forward when it comes to our exemplary model.

Discussion

In this paper we examined primary student teachers' conceptions about good science teaching. In the pre-conceptions the most frequent category, teaching methods, emphasized that teaching should in particular include outdoor education and methods related to experimentation. The topic which most frequently emerged with regard to pedagogy and instructional decision making was practicality. The communication category included student teacher notions of practicality and group work. These views seemed to be very traditional and may be derived from student teachers own experiences as pupils (Abell, 2000).

The pre-conceptions revealed that inquiry-based teaching is not sufficiently present in student teacher understanding. The problem-based approach was particularly lacking when thinking about the standards for inquiry-based teaching. Classroom communication, and especially dialogic teaching, was also something that was not explicitly considered in the pre-conceptions. Taking pupil pre-conceptions into account was, however, something that student teachers mentioned at this early stage.

The learning profiles of the six student teachers revealed that with the exception of two cases there was progress in the student teachers' conceptualisations of inquiry-based teaching and dialogic teaching. At the end of the course, four of the student teachers reached the standards for inquiry-based teaching and learning (National Research Council, 2000). When considering our exemplary model about dialogic-inquiry based learning, the same four student teachers could be considered to have established a basis for implementing this kind of teaching in practice. In particular the 'opening-up' phase of inquiry-based teaching and the notion of taking pupils' pre-existing views into account were adopted. The 'closing-down' phase, however, was not stressed in the student teacher conceptions. It may be that student teachers still lack understanding of the importance of taking both aspects of communication, dialogic and authoritative, into account. They may see this matter as too black and white, meaning that they see teaching either as pupil-centred (related to dialogic) or teacher-centred (related to authoritative), rather than recognising the importance of both. In relation to this, some preliminary results suggest that combining authoritative and dialogic approaches provides the most benefit for pupils' learning outcomes (Furtak & Shavelson, 2009). Whilst various situation-oriented strategies can establish this, our exemplary model for dialogic inquiry-based teaching provides one holistic way of considering these two approaches of communication when planning and implementing science classroom inquiries.

Implications

This study has provided insights into primary student teachers' pre-conceptions of good science teaching and examples of different types of learning profiles related to inquiry-based teaching and dialogic teaching. As an analytical implication, we consider that our framework highlighting the social aspect of inquiry-based teaching could be useful in studies aiming to examine interactions taking place in inquiry-based classrooms. This kind of analysis could reveal whether the inquiry is authentic or whether the teacher is hindering pupils' reasoning via overly authoritative approaches. Within an authentic inquiry teacher opens up space for pupils to conduct the inquiries without controlling pupils' thinking, thus authoritative approach should not be prevailing approach.

This dialogic inquiry-based framework could be useful in teacher education programmes which aim to highlight the importance of scientific inquiry. Since the principles of the inquiry-based approach provide very broad guidelines, it is arguably important to introduce student teachers to more explicit concepts, such as the communicative approach, addressing the complexity of classroom interactions. However, different approaches should also be planned and practised during initial field experience. The dialogic approach in particular requires concrete practice (Lehesvuori, Viiri, & Scott, 2009). The aim of the framework we have presented here is to provide an overall structure for planning (dialogic) inquiries, which according to Zubrowski (2007, p.862) is an elemental factor when implementing inquiry components into practice. The extent student teachers apply dialogic inquiry-based approach theoretical framework into practice should be examined in further studies. Preliminary results indicate varying success among science student teachers in adopting dialogic approach in secondary science lessons (Lehesvuori, Viiri, & Scott, 2009). As brought up, explicit practising is required to overcome challenges like question of time and discipline (Scott, Mortimer, & Aguiar, 2006) in order to change the prevailing authoritative climate of science classrooms.

Whilst our study reported here examined student teachers, our exemplary model could equally be applied to in-service education. The objective of in-service education would be the incorporation of dialogic inquiry-based methods in science into effective teacher professional development programmes with a view to improve attitudes, motivation and career choice disposition towards science for pupils.

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APPENDIX 1. The framework for the mid-interview

Conceptions

1. Why is science taught in primary school?
2. What do you think is good science teaching?
   →Draw a concept map about this. Add everything that is included in good science teaching according to you (15 minutes)
3. What teaching methods would you like to use in primary schools science?

Inquiry-based teaching

4. What do you think inquiry-based teaching in science is?
5. During the course there has been a talk about inquiry-based teaching. Do you think you have acknowledged the idea of inquiry-based teaching?
6. What do you consider the most crucial thing in inquiry-based teaching?

Dialogic teaching

7. What kind of teaching is dialogic teaching?
8. What do you consider as a good dialogic learning process? Give an example.
   - How do you think a teacher should act if pupils clearly signals misconceptions about some phenomena?

Course experiences

9. What do you think you have learnt during the course so far?
10. What do you think has been the most important thing so far?
11. Were the terms inquiry-based teaching and dialogicality familiar to you before the course?
12. What kind of experience has the course given so far?
13. What have you spent time on during the course and demonstrations?
14. Do you consider the teaching during the course could as resembling dialogic inquiry-based teaching?
15. What is your goal for the rest of the course? What would you like to learn more about?

APPENDIX 2. The framework for the post-interview

1. What do you think inquiry-based teaching in science is?
2. What is the most crucial part of it?
3. What do you think dialogic teaching is in science?
4. What is the most crucial part of it?
5. What do you think dialogic inquiry-based teaching is?
6. What is the role of the teacher in dialogic inquiry-based teaching?
7. What is the role of the pupil in dialogic inquiry-based learning? Do you consider pupils in average have the abilities for this kind of learning?
8. What is the aim of the dialogic inquiry-based teaching?
9. Do you consider yourself as using dialogic inquiry-based (learning) teaching? in-service? Why/ Why not?
10. What do you think is the aim and purpose of primary school science teaching?
11. Assemble good science teaching in five sentences. Encapsulate everything you consider as crucial.

IV

INQUIRY-BASED APPROACHES IN PRIMARY SCIENCE TEACHER EDUACTION

By

Sami Lehesvuori, Ilkka Ratinen, Josephine Moate & Jouni Viiri submitted for publication

Inquiry-based approaches in primary science teacher education

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Abstract: This chapter introduces an exemplary model for inquiry-based science teaching and education (IBST/E) in interaction with an interactional graphic tool (Viiri & Saari, 2006) for science-based classroom interaction. Combined the model and graphic tool offer an approach to support the planning, execution and analysis of dialogic IBST/E. The context for this exploratory study comprised of student teachers learning to use IBST/E ideas in their teaching. The model and interactional graphic are fundamentally related to three established approaches to science teaching. These complementary approaches are inquiry-based science teaching, dialogic teaching and the Communicative Approach (Mortimer & Scott, 2003). Together these approaches draw attention to learner participation (inquiry-based science teaching), the joint construction of understanding (dialogic teaching) and the alternative types of talk teachers can use to guide learning in science (Communicative Approach). Combining these three approaches provides a broader 'three-pronged' approach to teaching-learning in science. Where, for example, the inquiry-based approach may fail to provide a deeper understanding of complex interactions in inquiry-based science classrooms, the dialogic and communicative approaches explicitly focus on the teacher's communicative role during different phases of the inquiry. On this basis, we refined our primary teacher science course to include ideas from both inquiry teaching and classroom interaction. During the course, in addition to analysing the content structure of climate change, examining textbooks, pupil thinking and their preconceptions, the student teachers also explored the fundamental ideas of dialogic IBST/E in primary schools. The researchers then used the interactional graphic to map student teachers' communicative patterns and to analyze the extent to which they had adopted the IBST/E approach. The potential use of the IBST/E approach for the professional development of in-service teachers is considered towards the end of the chapter.

Keywords: inquiry, communicative approach, dialogic teaching, interactional graphic

Introduction

This chapter introduces an exemplary model and an interactional graphic tool for science-based classroom interaction used to map and analyze science-based classroom interaction. The specific context for the case-study presented in this chapter was a student teacher group learning to use dialogic IBST/E ideas. The exemplary model was used to introduce the student teachers to the basic notions of IBST/E and the interactional graphic offered a means to map the communicative approaches used by them during teaching. Mapping the communicative approaches of the student teachers in this way provides a visual record of the interactional patterns employed in the science lessons. This visual illustration provides a useful tool for both reflecting on classroom interaction and identifying areas for further development, applicable to both initial and in-service teacher development.

Theoretical aspects for dialogic inquiry-based teaching and learning

The main concepts drawn upon for our theoretical framework are inquiry-based learning, dialogic teaching and the Communicative Approach. These conceptualisations of science education provide the foundation for both the exemplary model and interactional graphic. It is interesting to note that whilst inquiry-based approaches tend to overlook the dialogic aspect of science teaching and learning, the guidelines of inquiry-based approaches are, in many ways, related to the fundamental ideas of dialogic teaching. The depth of understanding offered by dialogic and communicative approaches concerning the complex interactions of science teaching-learning complements an inquiry-based approach. Furthermore, including dialogic and communicative approaches in science education addresses concerns about the lack of openness in inquiry-based approaches. Without explicit attention to pupil understanding, often it can appear as though learners are working towards predetermined outcomes, as though they were following a prescribed recipe towards the desired outcome (Sadeh & Zion, 2009).

A fundamental aim of dialogic teaching, however, is to explicitly extend pupil reasoning and understanding. Pupil activity is essential in dialogic teaching. The key characteristics of a dialogic approach (Alexander, 2006) can be briefly described as being:

- collective: teacher and pupils jointly participate in the learning as a group or as a class
- reciprocal: teacher and pupils listen to each other, share ideas and consider alternative views
- supportive: pupils can present their ideas freely without fear of being incorrect
- cumulative: teacher and pupils develop their ideas together, jointly constructing knowledge
- purposeful: the teacher plans and guides the discourse paying attention to educational goals in addition to the above points.

Of these characteristics, the aim to develop ideas cumulatively, is particularly difficult to achieve (Alexander, 2006) and requires that the teacher has high-quality professional skills including genuine subject knowledge, appropriate pedagogical skills and an understanding of the capacity of each child in order to take learners' thinking forward. Within a dialogic approach, as described by Alexander, learner participation is of the utmost importance and this in turn addresses motivation and deeper learning, countering the 'recipe-threat' mentioned earlier. However, in our opinion, this dialogic approach does not stress adequately the authoritative aspect of science education. The gap between pupils' pre-existing views and the scientific view is often too great to be addressed using the dialogic aspect alone. It is this dimension that is addressed by the Communicative Approach – the third prong of IBST/E.

Mortimer and Scott's communicative framework accommodates both dialogic and authoritative approaches in the science classroom. According to Mortimer and Scott (2003) classroom discourse consists of four categories generated from the combination of two dimensions: interactive/non-interactive and authoritative/dialogic (Mortimer & Scott, 2003). Using 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 dimensions indicate the different ways in which teachers can use talk, whether through whole class discussions, question/answer sessions or teacher-talk. Scott and Ametller (2007) stress that meaningful science teaching should include both dialogic and authoritative aspects and that the relationship between these two aspects is highly significant. For instance, if discussions are 'opened up' through a dialogic approach and pupils are given the opportunity to work with different ideas, at some point discussions should also be 'closed down' using an authoritative approach. The 'closing down' phase is potentially very important, for example when clarifying the differences between pupil everyday views and the scientific view.

Dialogic inquiry-based teaching and learning

To meet the challenge of implementing inquiry-based learning with dialogical aspects and educational goals, we developed an exemplary process model to take these different aspects into account (Table 1). The model could also be considered as a theory-based planning tool for dialogic inquiry-based learning with both dialogic and authoritative modes included in the table. The first column of the table lists the different phases of an inquiry. The subsequent columns indicate how each phase addresses key notions from each of the three approaches.

Table 1. Exemplary model for dialogic inquiry-based teaching and learning.

	Inquiry-based learning	**Communicative approach**	**Dialogic teaching**
Initiation phase	-Problem-based approach -Considering pupils' pre-conceptions	-Opening up phase: -Dialogic and interactive -Dialogic and non-interactive	Supportive Reciprocal Collective Cumulative Purposeful
Inquiry phase	-Planning -Making hypotheses -Collecting information -Executing the inquiry	(- Emphasis is on pupil-pupil interaction)	Collective Cumulative Purposeful
Reviewing phase	-Comparing results to the scientific view -Creating models -Argumentation -Reinforcing the scientific view	-Closing down phase: -Dialogic and non-interactive -Authoritative and interactive/non-interactive	Supportive Reciprocal Collective Cumulative Purposeful

The *initiation-phase* includes examining pupils' pre-conceptions, and even though pre-conceptions at this point might be considered misconceptions, pupils should be given an opportunity to express them. Using a problem-based approach the teacher could uncover these (mis)conceptions by employing a dialogic approach and opening up problems requiring inquiry. At a later stage the views can be reflected upon again, seen in the light of the executed inquiry.

The *inquiry-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 of a tutor than director, in this way creating the ground for meaningful planning and inquiries. Although pupils are expected to do the thinking, the teacher could still raise questions that guide pupil work and thinking further. We emphasise that in this phase the teacher should focus on encouraging pupil-pupil interaction.

The *reviewing-phase* is essential when it comes to achieving educational goals. Although in this phase more authoritative communication is emphasized, any pre and misconceptions should be reviewed against the scientific results and theories in order to make the connections between views (e.g. everyday views and the science view) explicit and also highlight possible weaknesses in previous thinking. While different ideas are still being considered, the dialogic approach should also be used. The authoritative approach should continue to be implemented when making the final conclusions about the content and also about the procedure itself. Therefore, when problems are opened up (dialogic approach) they should be also closed down (authoritative approach).

The design and development of a training module for dialogic IBST/E

At the University of Jyväskylä, the science education course for primary student teachers is nine credits of the total Master's degree of 300 credits (ETCS). The course covers one academic year, beginning in September and ending in March and includes subject lectures, didactic seminars, project work and teaching practice in schools.

The course *lectures* contain various elements of science teaching to familiarize primary student teachers with dialogic inquiry-based science teaching and learning such as models in science, pupils’ conceptions, evaluation, planning teaching. These general topics deal with different areas of science (physics, chemistry, biology, geography). Before each lecture students study the study material familiarising themselves with the lecture. At the beginning of every lecture *content tests* evaluate students’ prior content knowledge of the given issues. The aim of the content tests is to both activate student prior knowledge and to provide lecturers with information regarding student teacher conceptions.

The didactic seminars focus on dialogic inquiry-based learning. The first seminar introduces the course principles, the study project ideas, and inquiry-based learning and is then followed by four specifically science education seminars. The seminars of the case-study student group concentrated on climate change and linked the physical, geophysical, chemical, biological and environmental aspects of climate change. The topic of climate change was chosen as it is socially and environmentally important and an interesting topic. It was also hoped that as primary level student teachers are not science specialists, the relevant contextual framework might support student teacher interest in the science concepts and ideas.

The seminars also introduced the students to the following issues: what is science, how science works, and how dialogic inquiry-based teaching can be incorporated into science teaching. Moreover, during one of the seminars student teachers were introduced to the classification of teacher-talk based on the Communicative Approach of Mortimer and Scott (2003). Student teachers were provided with different examples of teacher-talk with directions for classifying classroom interaction. They then visited a local primary school and observed a class they were to teach during the implementation phase of the planned teaching sequence. They completed a specific observation form during the science lesson and classified the teacher-talk according to the different communicative approaches. The aim behind this classroom-based experience was to prepare the student teachers for the planning for and inclusion of different communicative approaches within their own teaching.

The *study project* is the core of this science education course and its objective is for student teachers to develop a teaching-learning sequence on a single science topic. The project includes: content analysis, discovering pupil ideas regarding the chosen topic, finding, selecting or creating the most appropriate presentations and teaching strategies, and making a plan for a teaching-learning sequence covering several lessons. The study project also requires students prepare a written report and oral presentation of the main issues of the project. The case-study students prepared to teach different topics related to climate change, e.g. the melting of polar ice, the greenhouse effect. Most of the teaching of the course (lectures, group work, assignments, etc.) supports the study project.

An interactional graphic tool

The interactional graphic tool (Figures 1-4) aims to present the different communicative approaches and periods of inquiry within a lesson, in a readily accessible format. The vertical axis of the diagram displays the four different classes of the Communicative Approach (Mortimer and Scott, 2003) with the fifth, uppermost section of the axis representing the inquiry phase of the lesson during which pupil-pupil talk is emphasised. The example in Figure 1 is taken from one of the case-study student teacher lessons, (Class A) explained in detail later.

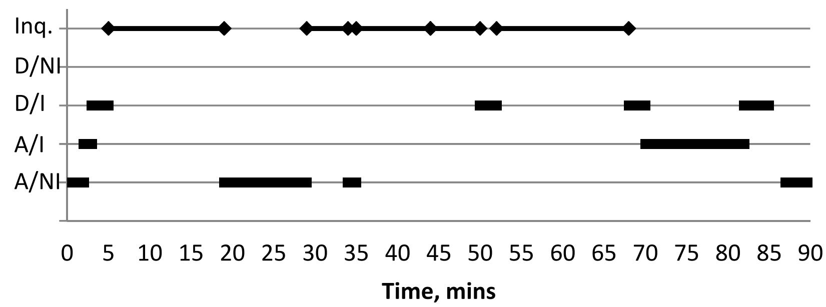

Figure1. Lesson diagram of Class A. (A/NI = Authoritative and non-interactive, A/I = Authoritative and interactive, D/I = Dialogic and interactive, D/NI = Dialogic and non-interactive, Inq. = Inquiry phase).

In Figure 1 the initial opening-up phase is characterized by the different communication approaches used by the teacher. The duration of a particular approach can be estimated from the horizontal axis. This opening-up phase leads into periods of inquiry-based activities punctuated by further guidelines given by the teacher, in this instance through the reading of a story. The communicative approaches adopted by the teacher towards the end of the lesson indicate the closing-down phase with increased emphasis on the scientific view. Mapping the interactional patterns of the lesson in this way provides an overall picture of classroom talk. The interactional graphics of different lessons can be placed alongside each other supporting comparisons between lessons. Though the interactional graphic does not ‘judge’ the interactional choices of the teacher, implicit in the representational style of the graphic is the need to reflect the three-part structure of the exemplary model: the opening-up phase of the inquiry, the inquiry itself and closing-down the inquiry. The pattern could be applied across a entire course of study on a particular topic, but the case-study group of student teachers prepared a ‘stand-alone’ double lesson during which they employed the IBST/E approach.

Participants

The overall course participants (about 120) were divided into six seminar groups of approximately 20 students. Each group had a specific university lecturer to mentor student work. The groups were further divided into subgroups consisting of 4-5 students. The students planned and implemented the teaching practice lesson as a subgroup. The data collection and analysis presented in this chapter is based on one group, the case-study group, mentored by the second author of this chapter.

Recorded lessons

The student teachers’ video-recorded lessons provided the main data for this chapter. Each of the student teacher lessons were mapped using the interactional graphic providing a visual representation of the lessons with the interactional patterns clearly identified. Supplementary, contextual data included student lesson plans and interviews after the lessons. The lesson plans were then analyzed by the second author to see whether and how the students had implemented the ideas of dialogic inquiry-based teaching in their lesson plans (an example plan is provided at the end of the chapter). Following the lessons, stimulated recall interviews conducted by the second author were used to analyze students' opinions about their aims and success in their teaching. Once the collected data were mapped with the interactional graphic for each group it was possible to compare the degree to which the student teachers implemented the principles and practices of IBST/E.

Teaching sequence examples

This section includes interactional graphs and contextualising comments for each of the four student subgroups and a description of Class A’s lesson. It is hoped that the interactional graphic examples applied to the context of student teacher science lessons illustrates the greater potential of this tool in studying science-based classroom interaction.

Class A

The topic of this lesson was the melting of polar ice. The communicative approaches and active inquiry phases of the lesson are graphically presented in Figure 1 above. First the four student teachers briefly introduced themselves to the pupils. Then one student teacher asked pupils about the melting of clean and dirty ice (minutes 3-5). He collected pupil ideas without directly evaluating the answers and in this way pupils' prior ideas were taken into account before group work began. According to the lesson plan (see procedure 2 in the lesson plan in the Appendix), the communicative approach planned was interactive/dialogic.

After brief instructions pupils started to work in groups on three tasks: the greenhouse effect, a drawing assignment and planning an advertisement. The melting of two different types of ice was measured by the teacher at approximately 15 minute intervals while the whole class was encouraged to make observations.

The second task (minutes 29-44) began with a story about a polar bear and the melting of a north polar glacier. After the story pupils were asked to draw a cartoon based on the story and to think about the consequences of climate change. The third task (minutes 44-68) required that pupils planned an advertisement to encourage the slowing down of climate change. Once again the task was momentarily interrupted for whole class measurements. After this the teaching sequence continued with a role play activity (minutes 70-82). Each pupil was given a role (e.g., polar bear, atmosphere, sun ray, etc.) and every time this character was mentioned in the story the pupil(s) demonstrated the actions of this character. The pupils seemed very enthusiastic when playing their roles and explaining the reasons for the melting of a polar glacier. In this way pupils were introduced to the conclusions drawn during the final parts of the lesson.

The final measurements were conducted and observations were made on the quantity of melted ice. During this phase interactive/dialogic communicative approaches were used, although authoritative passages gently guided the discussions towards conclusions. Pupils pre-conceptions were then addressed within the final conclusions (minutes 82-90).

The planned procedures, including communicative approaches, can be clearly identified in the teaching sequence, which illustrates the purposeful use of different discursive strategies. During the dialogic episodes pupil contributions were especially taken into account with a supportive or neutral tone, thus fostering an open climate for further contributions from pupils. In addition to purposefulness, other features of dialogic teaching were also present in both the lesson and lesson plan. For instance, acknowledging pupils' prior ideas and addressing these at the end engages both supportive and cumulative teaching. Furthermore, pupil group work with student teachers acting as co-inquirers aimed to embrace collective and reciprocal approaches to pupil inquiries. However, when this aspect was discussed in the interviews student teachers identified it as being challenging. They thought that they were renegotiating rather than guiding pupils in a certain direction, indicating the challenge of balancing dialogic and authoritative approaches. This challenge is also evident in the lesson plan. Procedure 4 indicates a clear conflict between adopting an interactive/dialogic approach and "finding the right answers with teacher's support". However, in conclusion the structure of the planned teaching sequence closely followed the approach for planning and implementing dialogic inquiry-based learning.

Class B

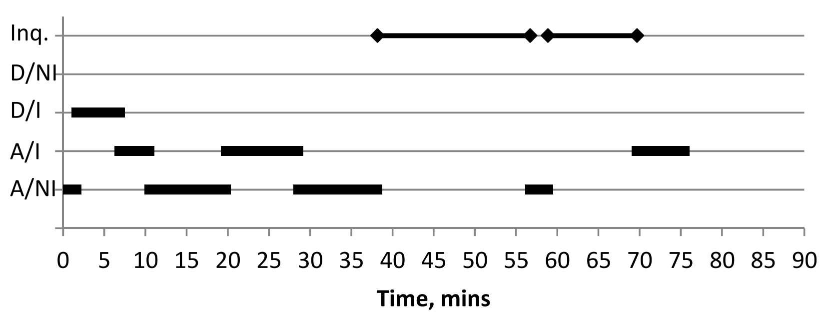

Figure 2. Lesson diagram of Class B. (A/NI = Authoritative and non-interactive, A/I = Authoritative and interactive, D/I = Dialogic and interactive, D/NI = Dialogic and non-interactive, Inq. = Inquiry phase).

The topic of Class B was CO_2. The teaching sequence mirrors to some extent the model of dialogic inquiry-based learning. However, the dialogic opening phase is closed before the actual inquiries. This can be seen as the authoritative episodes dominating between minutes 7-38. The inquiry phase itself is carefully planned and pupils have the freedom to peer evaluate the results before a student teacher reviews the essential points. During this phase an even more authoritative and goal-directed approach would have been appropriate for the closing phase of the inquiry.

Class C

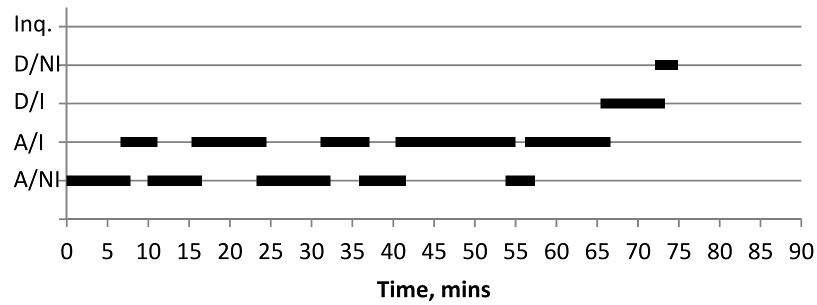

Figure 3. Lesson diagram of Class C. (A/NI = Authoritative and non-interactive, A/I = Authoritative and interactive, D/I = Dialogic and interactive, D/NI = Dialogic and non-interactive, Inq. = Inquiry phase).

This teaching sequence dealing with climate change does not follow the dialogic inquiry-based learning approach. This example fails to employ the full range of communicative options, and as can be seen from the interactional graphic where periods of inquiry-based activity are completely absent from this lesson. Whereas Class A effectively illustrates the three-part pattern of the exemplary model, Class C neither opens-up nor closes-down rather it maintains the authoritative view of science throughout the lesson omitting any authentic phases of inquiry or dialogue.

Class D

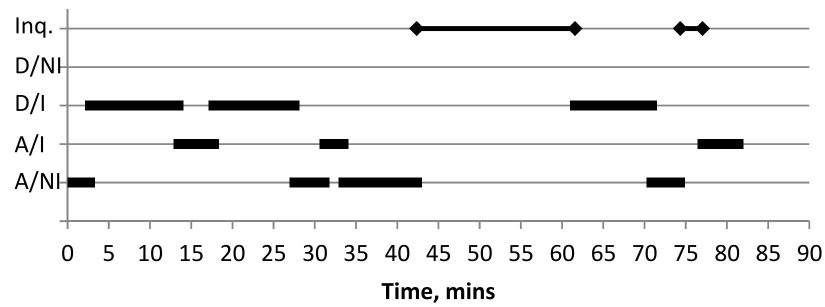

Figure 4. Lesson diagram of Class D. (A/NI = Authoritative and non-interactive, A/I = Authoritative and interactive, D/I = Dialogic and interactive, D/NI = Dialogic and non-interactive, Inq. = Inquiry phase).

Class D studied thermal zones and the relation of planetary phenomena to climate change. This teaching sequence partially follows the approach for implementing dialogic inquiry-based learning: Pre-conceptions are mapped and brought forth before executing inquiries. Additionally, at the end the essential concepts are reviewed. However, despite the dialogic episodes in the first phase, the student teachers are concerned with scientific correctness at this point. As the diagram reveals there are authoritative episodes after the dialogic ones before the actual inquiry; the dialogic model therefore is not fully implemented.

Discussion and conclusion

The aim of the course was to introduce teacher students to dialogic inquiry-based science teaching and education. The model presented in Table 1 provided the theoretical background for the ideas dealt with both in lectures and didactic seminars. We evaluated the impact of the course by investigating how student teachers could implement the ideas of dialogic inquiry-based teaching in actual classroom teaching. This evaluation was carried out using the exemplary model and interactional graphic tool. Together these provided the analytical structure and visual representation of the interactional approaches used in the classroom. As the examples revealed only one group implemented most of the ideas successfully. The students of this group demonstrated their ability to plan, implement and critically evaluate the dialogic inquiry-based science classroom.

This chapter suggests a complementary combination of dialogic teaching and inquiry-based learning in order to provide both new theoretical and practical tools for analyzing and planning inquiry-based learning sequences. As the interactional graphs illustrate, the analysis revealed different levels of success in terms of implementation of dialogic inquiry-based learning. Whereas in the case of Class A the graph illustrated an exemplary approach to executing a dialogic inquiry-based teaching sequence, student teachers in Class C did not resort to the provided model at all. Rather, the communicational structure of Class C resembles the traditional teaching consisting of IRE-patterns (Lemke, 1990).

We believe there are many reasons for the varying success of the student teachers. One of the main reasons hindering the development of dialogic discussions might be the insufficient scientific content knowledge of primary school teachers (Childs & McNicholl, 2007). Other possible reasons might be the prevailing classroom communication culture, group dynamics, topics, etc.. Furthermore, student teachers may well need more concrete practice implementing a dialogic approach. An interesting option for further research would be to use the graphic representations with student teachers and in-service teacher professional development (PD).

The graphical tool is a novel means for analyzing and presenting teaching sequences in educational research with significant potential. In addition to being used during planning, the model would be useful during the process of reflecting on teaching practice as we have demonstrated in the formal analysis of classroom interaction. As an application for teacher education, the interactional graphics could be useful in student teacher observations of classroom practice. As part of the science education course used in this research, the student teachers observed a science lesson and made individual notes according to a prepared format. An extension to this task could be for student groups to construct an interactional graphic of the observed lesson. This would encourage student teachers to truly engage with the different interactional options and to clarify what these mean in practice. This should further support student teachers in lesson planning and the realization of IBST/E.

This study aimed to reform student teachers traditional authoritative view of science teaching, but there are still major challenges ahead when thinking about adopting the dialogic aspect. Aside from the question of time and discipline (Scott, Mortimer, & Aguiar, 2006), the dominant school culture may not be open to dialogic innovations. Moreover, these challenges are arguably also applicable to the professional development of in-service teachers. In order to challenge this prevailing culture, dialogic issues need to be emphasized in initial and in-service teacher education. Often, however, teachers are not able to effectively use the appropriate pedagogical strategies discussed in PD courses. Indeed, teachers' perceptions and methods of teaching are deeply grounded in their own experiences of school as pupils (Abell, 2000). If PD does not 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 is essential in initiating reform of practice (Kagan, 1992). The theoretical model and interactional graphic are presented here as two key tools in the introduction and development of dialogic innovations in science education applicable to both initial and in-service teachers.

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APPENDIX: LESSON PLAN

Level:	**Time and date**:	**Topic / objectives**: Science: Climate change and its influence on the life of glaciers
6	2x45min (90min) 22.2.2011	**Summary of special education** Every pupil can participate according to her/his abilities. Group work: attention to individuals.

Educational and learning objectives:	**Learning process, content, time management, specialization:**	**Procedure**	**Evaluation and feedback**
Educational objectives: • dialogue and interaction • group work skills • stimulation of individual thinking Learning objectives: • Understand the causal relation of climate change. • Understand the greenhouse effect vs. climate change • Understand the complexity of climate change. • Accessing the experiment: ice cube demonstration. Small group work supports the consideration of individuals and their needs.	1. Opening class: topic presentation (5min) 2. Setting experiment (10min) • Experimental design. • Linking to glaciers. • Making hypotheses. • Tabling on blackboard. 3. Forming groups (each 5 persons) (2min) 4. 1st task: What causes climate change? Completing picture with teacher guidance (15min)* 5. 2nd task: What follows from climate change? Drawing picture based on story (15min)* 6. 3rd task: How to prevent climate change? Making an ad based on given material (15min)* 7. Synthesis: What is it? Pupils play a drama (15min) 8. Reviewing the experiment: Is the hypothesis true? Why or why not? (13min) *) At the end of each task, the melting ice is observed.	1 Non-interactive/authoritative: Teachers present the topic of class. 2 Non-interactive/authoritative: Setting and explaining experiment. Dialogic: Collecting and discussing of hypothesis. 3 Non-interactive/authoritative 4 Interactive/dialogic : Group discussion with teacher tutoring. Finding the right answers with teacher support. 5 Non-interactive/authoritative: Teacher reads the story to pupils. 6 Interactive/dialogic: Pupils negotiate the story and draw a picture. 7 Interactive/dialogic: Pupils seek information and teacher help if needed. 8 Non-interactive/authoritative: Teacher reads the story to the end 9 Interactive: Pupils act the drama. 10 Dialogic: Pupils explain their observation of ice melting. Discussion about hypothesis.	Teachers support and encourage during every task-> direct feedback Eg. understanding the meaning of the experiment-> Why we did as we did? Evaluation new conceptualization (new drawings): • Do pupils understand the connection and difference between the greenhouse effect and climate change? • Has pupil knowledge of climate change increased? • Do pupils understand the connection between climate change and glaciers melting? Include both individual and group evaluation plus feedback.