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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' preconceptions	-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: -experimentations -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).

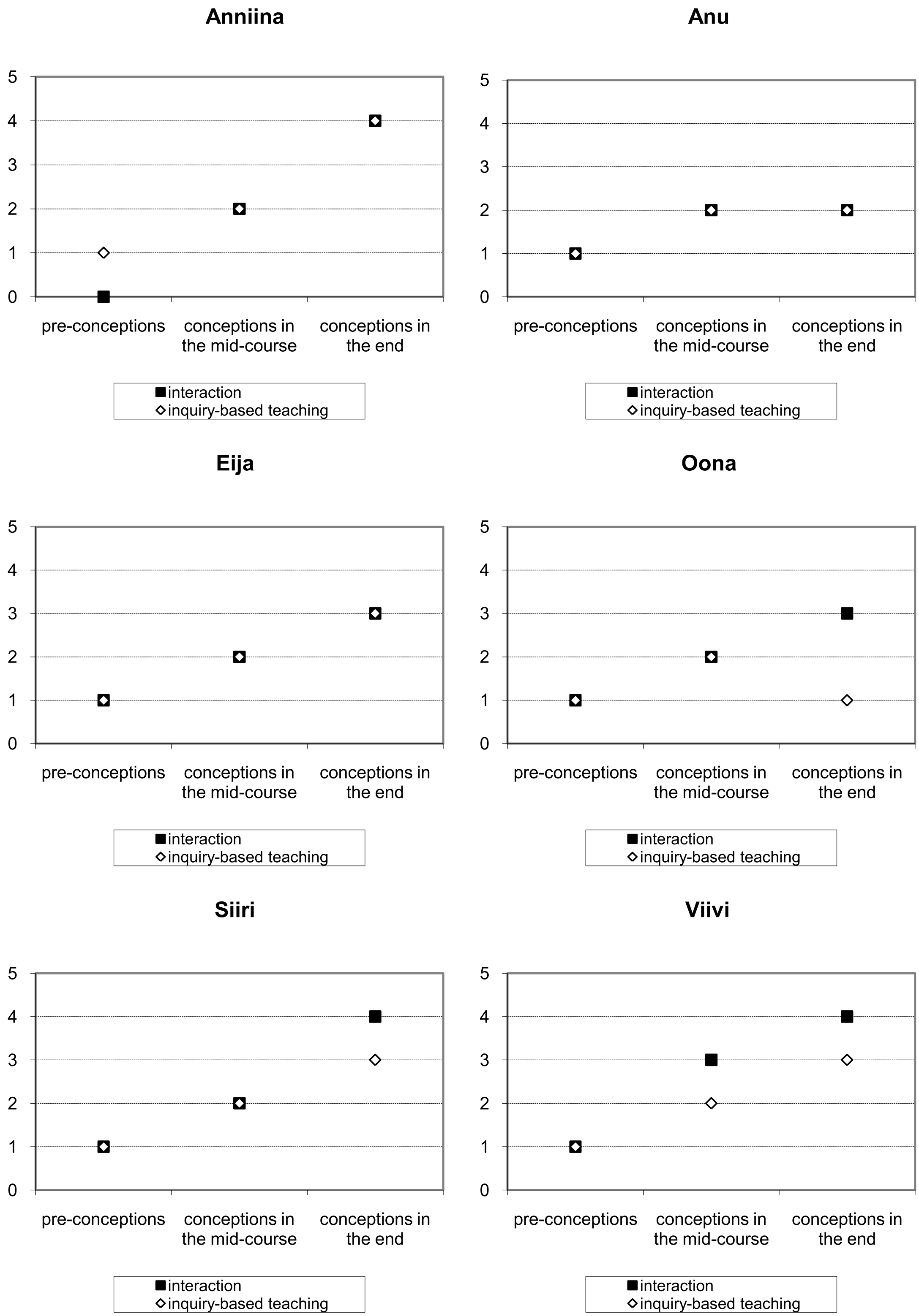

Figure 1. Overview of the learning profiles.

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

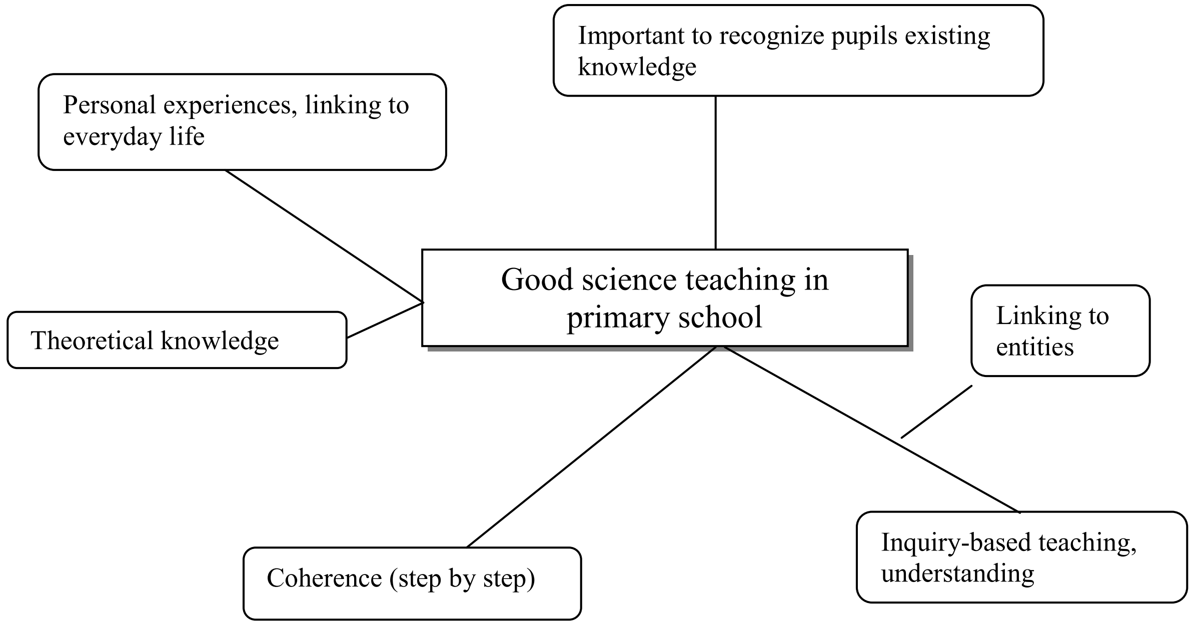

Figure 2. Anniina's concept map.

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.