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EXPLORATORY TALK IN SCIENCE EDUCATION: INQUIRY-BASED LEARNING AND COMMUNICATIVE APPROACH IN PRIMARY SCHOOL

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Abstract. *Recent research on science education has increasingly focused on the role of exploratory talk for learning science in school. This study was conducted in third grade in the Swedish compulsory school and shows how difficult exploratory talk in science is to achieve. The recordings of each lesson focused mainly on the teacher but included the pupils as the teacher interacted with them. The empirical material was analysed from two different perspectives: ways of communicating the science content and communicative approach. The analysis of the classroom practice showed that scientific descriptions were dominating ways of communication. Only in a few cases explanations of scientific phenomena were in focus. Those situations caused turning points into more interactive/dialogic communications or exploratory talk. One main conclusion is that exploratory talk and scientific explanations are not easily achieved when working in primary school. These skills are not automatically attained by the use of inquiry-based material – it needs to be trained!*

Key words: *exploratory talk, inquiry, primary school, science.*

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Introduction

Inquiry plays an increasingly important role in science education. Inquiry-based Science Education (IBSE) focuses on pupils' inquiry as the driving force for learning. Teaching in this perspective is organised around questions and problems in a pupil-centred process. However inquiry-based science education can be characterized in different ways. But in any case practical work and communication are important elements (Harlen, 2009).

Practical Work in Science Education

The reasons for using practical work in science education are many and different; the pupils learn the nature of science, the scientific phenomena are presented in a context and scientific methods and concepts are used in functional ways. In accordance with this Jenkins states that it is only through laboratory work the pupils can get a "feel for the phenomena" that science seeks to understand or explain (Jenkins, 1999, p. 29). Practical work is one of the most important features in science education and many schools devote considerable resources to give pupils the opportunity of doing practical work in their science lessons. It is also supposed to be a link between the empirical/observable and the theoretical/non-observable (Jenkins, 1999; Sjøberg, 2000, p. 392-394). Watson (2002) points out the importance of observations and descriptions to promote logical reasoning. But the teachers must teach the pupils how to observe and how to describe what is worth, and not worth, paying attention to in a science experiment. Bergqvist and Säljö (1994) describe how difficult it can be for the pupils to pay attention to the right things in a laboratory situation and how much guidance they need from someone more knowledgeable. This implies that the pupils must get opportunities to use relevant equipment and get feedback on their observations through communication with a more experienced person (Goodwin, 1997). Introducing scientific practices to young pupils in school is difficult (Berg, Löfgren & Eriksson, 2007) and the pupils need guidance from the teacher on this journey (Schoultz, 2000). Appleton found in his studies (Appleton, 2002, 2003) that teachers in primary school, who often have limited science knowledge, preferred science activities that were interesting and fun for the pupils, fairly safe to manage for the teacher and predictable in outcome.

But when studying science, the pupils have to familiarize themselves with a special mode of seeing the world. Accordingly, learning science directly from practical work is difficult and more and more researchers pay attention to talking science and the importance of language in science education (Lemke, 1990).

Learning Science, Language and Communication

Science education can be viewed as a specific culture or indeed a group of sub-cultures, which have been developed over a long period of time (Lemke, 1990; Aikenhead, 1996; Bruner, 1996). Here communication works with the aid of various concepts and terms, which can be differentiated from everyday language (Sjøberg, 2000, p. 314-316). Learning science is to become a participator in activities, which offer a scientific way of thinking, acting and talking. It means learning to control the use of the scientific language (Lemke, 1990). Wittgenstein (1953) talks about language game, which means the way we talk and use specialised conceptual language in reading and writing, in reasoning and problem solving and in guiding practical activities. The teaching of science in schools is an example of social and cultural activity, where there is a cultural overlap between the scientific knowledge cultures and the everyday ones (Andrée, 2007; Eskilsson, 2001). Wickman and Östman (2002) describe learning as a discourse change, a border crossing between everyday language and science language. The pupils must learn to discuss and to listen and reply to one another´s contributions, they must learn to use exploratory talk (Mercer 1995, Mercer & Dawes, 2008; Barnes, 2008). In exploratory talk the pupils are critically but constructively engaged in other´s ideas. To do this, they must feel comfortable in the classroom and dare challenge and discuss "half-baked" ideas (Pierce & Gilles, 2008, p. 43). But success of the communication in the classroom depends on the teacher and how he/she creates communities of inquiry. Just because several children are sitting together at a table does not mean that they are collaborating, they could simply be working in parallel on individual tasks (Mercer & Littleton, 2007). It takes time to learn and successful inquiry requires preparation, guidance and supervision from the teacher (Barnes, 2008).

Inquiry-based Science Education (IBSE)

IBSE has been identified as a 'key-concept' to primary science education (Harlen, 2009). It is a well-known agreement among scientists, policymakers, researchers, educators and science teachers that inquiry-based learning methods promote practical work and get students to reflect upon and discuss science tasks and learn more science (Crawford, 1997). IBSE is considered a key-concept for developing primary science education (Harlen, 2009), and an inquiry – based approach is supported by the European Union (Rocard, Cesrmley, Jorde, Lenzen, Walberg-Herniksson & Hemmo, 2007), and has led to great investment in IBSE in different European countries.

IBSE aims at creating an environment where meaningful science learning occurs and the pupils can learn about the nature of science and develop scientific ways of thinking (Crawford 1997; National Research Council, NRC 2000, 2001). By participating in inquiry-based activities, pupils can develop their ability to critically evaluate scientific data and models and understand what it means to do science and participate in a scientific community (NRC, 2001). Students who participate in inquiry activities are often motivated to learn science and develop positive attitudes towards science (Brown, 2000; Kubieck, 2005). Harlen and Allende (2006) list 14 descriptors for inquiry-based activities:

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- Gathering evidence by observing real events or using other sources
- Pursuing questions which they have identified as their own even introduced by the teacher
- Raising further questions which can lead to investigations
- Making predictions based on what they think or find out
- Talking to each other or to the teacher about what they are observing or investigating
- Expressing themselves using appropriate scientific terms and representations with understanding both in writing and talk
- Suggesting ways of testing their own or others' ideas to see if there is evidence to support these ideas
- Taking part in planning investigations with appropriate controls to answer specific questions
- Using measuring instruments and other equipment appropriately and with confidence
- Attempting to solve problems for themselves
- Using a variety of sources of information for facts that they need for their investigation
- Assessing the validity and usefulness of different ideas in relation to evidence
- Considering ideas other than their own
- Reflecting self-critically about the processes and outcomes of their inquiry.
- (Harlen & Allende, 2006, p. 26).

Although there is still a wide variation in the interpretation of the word "inquiry" in science education (Anderson 2002; Hofstein & Lunetta, 2004). In a study of the implementation of STC (Science and Technology for Children), a hands-on science program for children from The National Science Resources Centre, US, Jones and Eick (2007) describe three forms of inquiry-based learning. The first one is open-ended inquiry, which means that teaching is focussed on the exploration of students' questions, which is a process that should not be too restricted by timeframes. In the second form the teachers design projects based on discussions in the classroom and are often related to specific content topics and students' interests. The third form is guided inquiry where the science content and methods are fixed and structured and the pupils are working with hands-on activities in a stepwise plan. This clearly shows that inquiry-based learning can be interpreted and implemented in quite different ways. This research is needed to follow up and understand how the IBSE-concept is interpreted and implemented in the science classrooms.

Aim and Research Questions

The aim of the study is to explore scientific talk in primary school. The pupils in the study are 9-10 years old and work with inquiry-based science education material during their science lessons. The focus of the study concerns how the teacher presents the scientific content and the way the pupils are involved in the classroom communication. The main research questions are:

- In what ways are the scientific content communicated in the primary science classroom?
- What kind of communicative approach is dominating?
- In what way do those two communicative perspectives influence each other?

Methodology of research

Participants

Pupils in third grade and their teacher were observed for five science lessons. The teacher had about 15 years of teaching experience from grade one to grade six.

The school is a Swedish compulsory school and is situated in the country-side close to a town. The school is a so-called NTA-school, which means that they participate in the school developing programme NTA. The NTA program is described as a question-based inquiry oriented way of working based on experiments to give pupils opportunities to work as researchers. (NTA stands for Naturvetenskap och Teknik för Alla, which can be translated to: Science and Technology for All). NTA can be used from preschool to grade nine in the compulsory school. Today, NTA has become a widespread program in Swedish primary school, involving 109 municipalities throughout Sweden.

Instruments and Procedures

Two cameras were used in the classroom. One camera focussed on the teacher and the other on a group of pupils. The teacher also had a mp3-player around her neck to record her talk. During these five lessons they worked with different experiments concerning both physical and chemical changes. The working procedure in the classroom followed the same schedule during all lessons which means that the teacher introduced the new experiment before the practical work started. When the recordings of the five science lessons were finished we interviewed the teacher about those lessons. She chose to comment especially on the lessons where the pupils melted ice-cubes. Because of that we decided to analyse that particular lesson.

Data Analysis

The recordings of the lesson were transcribed and the transcripts were presented turn-by-turn. Turn according to Edelsky (1981) is an uninterrupted period of talk by same the speaker while she/he has the conversation floor. The conversation was literally reproduced but we have split it into sentences. Secondly, the transcripts were analysed to find different classroom activities, scenes or lesson segments to describe the lesson. Two lesson segments were found; instructions and practical work. The instruction was a whole class activity whereas practical work was carried out in smaller groups. In each lesson segment science sequences were further analysed. Accordingly, classroom activities that dealt with social instructions, discipline and other questions were excluded and not part of further analysis. Finally, the scientific sequences were analysed in relation to two analytical perspectives: ways of communicating the scientific content and communicative approach. To better understand and interpret what was happening during the lessons a semi-structured interview was performed with the teacher after the fifth lesson. The focus of the interview was her strategies in the classroom and how she was implementing the IBSE concept.

Analytical Perspectives

The empirical material, provided by video-and audio-recordings, was analysed in two different perspectives; ways of communicating the scientific content and communicative approach according to Mortimer and Scott (2003). The reason for focussing on these two areas is that they both provide useful analytical tools that can be used to describe an inquiry-based science education practice. By combining them it may be possible to further analyse classroom situations.

Analytical Tools for the Classroom Communication

Mortimer and Scott (2003) use the categories; descriptions, explanations and generalizations to describe the ways the scientific content are communicated in the classroom. Descriptions primarily focus on the macro-level which concerns observable or measurable properties such as mass, pH, and temperature. Explanations primarily focus on the non-visible sub microscopic-level and are used to explain the phenomena by the use of models such as atom-models and distributions of electrons. As an example solids can be explained in terms of packed atoms. Generalizations focus on laws and principles that go beyond the specific example or experiment in the classroom. Generalizations, according to Mortimer and Scott (2003), mean that a specific phenomenon, like a change in the physical state, can be described or explained by general laws or principles such as movement of atoms or molecules "[a] generalization goes beyond a description and an explanation in that it is not limited to a particular phenomenon, but express a general property of scientific entities, matter or classes of phenomena" (Mortimer & Scott, 2003,

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p. 32). However, 10-year-old children may not yet have been introduced to scientific explanations and generalizations. Acher, Arcà & Sanmartí (2007) argue that pupils of this age are unable to "to construct, or abstract, entities and processes of scientific consensus models," and cause of that "the science taught tends to be descriptive" (2007, p. 399). On the contrary, particle models introduced among 10-12 year old pupils have been shown to benefit pupils´ understanding of phenomena like melting and boiling (Papageorgiou & Johnson, 2005; Eskilsson, 2001).

Mortimer and Scott (2003) present an additional tool, for evaluating communication and meaning making processes in the classroom. It focuses on the role of the teacher and the way she/he helps the pupils to develop their knowledge. Four classes can briefly characterize the tool in the following way:

Interactive/dialogic. There are strong similarities with Barnes's (2008) definition of exploratory talk, which incorporates different ideas or opinions, explicit reasoning, critical but constructive engagement.

Non-interactive/dialogic. This dialogic approach is used when different (scientific) perspectives or possible solutions are presented by the teacher.

Interactive/authoritative. This can be compared to closed questions where one right answer exists in an Initiate-Response-Evaluation pattern (Sinclair & Coulthard, 1975).

Non-interactive/authoritative. This is comparable with a formal lecture where the students or pupils are listening and not involving in classroom talk. In the table below the four classes are summarized.

Table 1. Four classes of communicative approach (Scott & Mortimer, 2003; Scott, 2008).

	Interactive	Non-interactive
Dialogic	The teacher and the pupils discuss together different ideas and solutions of the problem.	The teacher points out different ways of solving a problem.
Authoritative	The teacher focuses on a certain aspect and guides the pupils to the right answer.	The teacher alone presents the content.

Ethical Considerations

Ethical aspects were considered by letting the parents and the pupils take part of an information letter about the project. In the letter we described the focus of the study, the data collection methods, and the way the recordings should be used. They were informed that personal names and the name of the school were to be concealed to provide anonymity. They all gave written consent to participate.

Reliability

The reliability of the study was also strengthened by joint analytic efforts and feedback in research seminars within the Explora research group (Ødegaard, Møller Andersen, Schoultz, Hultman, Lund Nielsen, Löfgren & Mørk, 2011) as well as in other national seminars (Löfgren, Schoultz, Hultman, Björklund, 2011). According to Merriam a case study is defined as "an intensive, holistic description and analysis of a single instance, a phenomenon, or a social unit" (Merriam, 1988, p. 21). A case can be "a program, an institution, a group, an event, a concept of special interest to educators (Merriam, 1998, p. 44). In a case study you cannot discuss generalizability in the same way as in a quantitative study.

Results of Research

The lesson started with an *instruction*, from the teacher for how to perform the new experiment. In this task the children were going to melt ice-cubes. First, they got instructions for how to describe the ice-cubes and how to write that down in their notebooks. Next they were told to work in pairs and put the ice-cubes in the plastic bags and figure out how to melt the ice-cubes as quickly as possible.

After that they started the *practical work* - to melt the ice-cubes. Finally, the lesson ended by putting the water, from the melted ice-cubes, in Petri dishes and placing them at different places in the classroom.

First we give a short presentation of each lesson activity and then we analyse it in two different ways followed by a short summary.

Lesson Part One: The Instruction

This classroom activity lasted for 20 minutes. A question about working in pairs during the practical work was raised by one of the pupils. The teacher explained in detail how they should handle this. This took about 2.5 minutes and is excluded from further analysis. Only 0.5 minutes were spent on disciplinary corrections and a short conversation how to use the ruler. The rest of this lesson part, 17 minutes, were further analysed for ways of communicating the scientific content and communicative approach.

Communicating scientific content

In the following, ways of communicating the scientific content under the instruction part of the lesson are described as; scientific descriptions, scientific explanations and scientific generalizations.

Scientific descriptions

The descriptions during the introduction focused on different aspects of the experiment. The first aspect dealt with instructions for how to write and draw in the pupils' booklets. The teacher had made prewritten papers for the pupils to copy. They were also asked to answer questions about the experiment afterwards and to write down the answers in their booklets.

The next aspect of instruction concerned the doing. Children were told to "look at it" but not "hold it". They were also told to put the ice-cube into a plastic bag and melt it.

> Teacher: /… /You get a tray and you put the ice-cube on that and then you look at it. You do not hold it! And then you write quickly what it looks like. And when we are ready and you have finished your writing you put the ice-cube into the little plastic bag. And then we come to the important thing today. Then we are going to melt the ice. /…/

The teacher tried to make the pupils describe the ice-cube. To help them, she had written two words, *cold* and *white* on the blackboard. She also told them to describe the form of the ice-cube. Some of the descriptions were observable (colour and form) whereas the temperature (coldness) of the ice-cube needed to be examined by touching the ice-cube.

> Teacher: /… / Look, I have written a few things down. I have written, as an example that you may think it is cold and white... Now you will describe the ice-cube. You shall write four things here around the [drawing of] ice cube. What you think the ice-cube looks like.

The teacher also described what would happen to the ice-cube if they did it too slowly. But it was obvious that the pupils already knew what would happen.

> Teacher: /… / What would happen if you are too slow? The experiment will be totally unsuccessful. Maria?
> Maria: It melts.
> Teacher: Yes.

In the interview the teacher commented on her strategies to instruct the pupils

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Teacher: I am very distinct in my instructions and I think they need it. Five of them may understand at once and could do it with less detailed instructions but most of them need in fact more instructions. /…/ This is because they are in third grade.

Scientific explanations

The teacher did not focus on explanations concerning the freezing and melting of ice. However, one explanation is raised by one of the pupils. This can be regarded as an explanation at the sub-micro level since the pupil really tried to explain the freezing procedure by referring to the movement of the atoms.

E: Warm water will freeze faster than cold.
Teacher: Do you think so?
E: It is like that.
Teacher: Have you tried that?
E: The atoms will move faster.
Teacher: In warm water yes?
E: That's why it becomes ice faster.
Teacher: Maybe it is like that.
E: Yes because I tried that.
Teacher: Yes.
E: With a, what shall I say, with a similar thing, with ice.
Teacher: With warm water?
E: One with warm water and one with cold water and put both in [the freezer].
Teacher: Yes.
E: And put a timer on five minutes. The cold was water.
Teacher: And the other was ice?
E: Yes.
Teacher: Is it like that? We must check that up later. /…/

Even though melting of an ice-cube can be regarded, as a simple and familiar phenomenon the explanation concerning the movement of the atoms can be difficult to handle. The experiment, that the pupil referred to, can be correct in that meaning that warm water evaporates so the volume decreases and therefore becomes ice faster than the cold water. It is not surprising that the teacher hesitated to continue this conversation.

Scientific generalizations

The teacher did not try to generalize the transition between the aggregation forms. One of the pupils tried to make up a general principal concerning the movement of the atoms and the freezing phenomenon. He was inspired by the freezing experiment discussed above.

Arvid: That thing that the atoms move faster. It seems logical.
Teacher: Yes.
Arvid: Everything seems to be freer for what so ever.
Teacher: That the atoms move faster, Arvid, that I know. One can show that in a way and I think we will do later, that the atoms in warm water move faster and that those in cold water move slowly. But then, to freeze in those different ways - that I do not know.

The different ways of communicating the scientific content during the instruction part of the lesson are summarized in the figure below.

Table 2. Ways of communicating the scientific content during the teacher's instructions (%).

Scientific descriptions	79
Scientific explanations	19
Scientific generalizations	2

As shown in table 2, the scientific content was presented mainly as scientific descriptions during the teacher´s instruction part of the lesson. It is interesting to note that the only attempts to explain or generalize the transition between different aggregation forms (solid to liquid), by use of atoms and particle models, is initiated by the pupils.

Communicative approach

In the following, the four classes of communicative approach from Scott and Mortimer (2003) is used to analyse the instruction part of the lesson; non-interactive/authoritative communicative approach; interactive/authoritative communicative approach; interactive/dialogic communicative approach and non-interactive/dialogic communicative approach.

<u>Non-interactive/authoritative communicative approach</u>

The non-interactive/authoritative communicative approach was the most common form of conversation during the instructions (50%, see table 2). For example, the teacher gave detailed instructions or information for how to write and what to write. The teacher also gave a small lecture about the Petri dish that they would use at the end of the lesson.

> Teacher: /… / And this little bowl. This little bowl has a special name. It is called Petri dish. It is a weird name. Why do you think it is called Petri dish? It was a man, who lived around 1870, it was quite a long time ago, and he worked with lots of experiments. And his name was Julius Richard Petri, his surname was Petri, and he was so smart so he invented this bowl. And this bowl is used today, for example in hospitals if you do experiments. So it is a very useful bowl that you will use later. You will pour water into it [the dish] and place them on different places in the classroom. You can see that they [the dishes] got a lid also. It [the lid] looks like this. /… /You will get a note from me later that you shall put under the dish when you have written your names on it.

<u>Interactive/authoritative communicative approach</u>

The teacher involved the pupils in the conversation concerning the experiment and possible outcomes of it.

> Teacher: /… / One other thing, we are also going to measure how long it takes to melt it [the ice-cube]. So you will have to, I will tell you when to start so we can all start at the same time. One of you has to look at the watch so we know how long time it takes. How long time, what do you think? Will it take very, very long time? Will it take an hour, or what do you think? Patrick?
> Patrick: A few minutes.
> Teacher: A few minutes maybe. Yes, a few minutes maybe. You will melt this. And what would happen? What will the ice-cube become when we have it melted? Richard?
> Richard: Water.
> Teacher: It will become water.

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Interactive/dialogic communicative approach

The teacher wanted the pupils to figure out different ways to melt the ice. The teacher gave instructions how to discuss this in smaller groups by giving a short dramatization of how to discuss.

> Teacher: /… / and then we come to the important thing today. Then we are going to melt the ice. And how can you do that, what do you think? Do you have any ideas? You will do it in your little group. Sarah and Richard will discuss with each other like this; "What do you think? How are we going to do to melt it? I think we shall do like this. I do not think that will work".

After that the interactive dialogue continued in the whole class.

> Teacher: But how can it be done, Edward?
> Edward: One can take hot water.
> Teacher: No, you are not allowed to get anything more.
> Edward: Nothing?
> Teacher: You have this stuff only and two persons in the group. Richard?
> Richard: One can keep the hands around so it gets warm.
> Teacher: Exactly. One can keep hands around. What else can you do Martin?
> Martin: One can put the sweater like this.

The teacher started with an open question how to melt the ice-cubes. After that she guided the pupils with different strategies how to melt the ice-cubes.

Non-interactive –dialogic communicative approach

The teacher did not discuss different points of view in this classroom activity so there was no non-interactive/dialogue communication.

The table below gives an overview of what kind of communicative approach that is made available during the introduction.

Table 3. Communicative approach expressed as percentage of the total time (17 minutes) of the instruction activity.

	Interactive	Non-interactive
Dialogic	31	0
Authoritative	19	50

Non-interactive/authoritative communication was the dominating communicative approach during the instructions. The teacher's voice dominated when she introduced how to write, what to write and also how to perform the experiment. The teacher explained in the interview, the need for detailed instructions for pupils in third grade.

Lesson Part Two: The Practical Work

When the pupils started to melt the ice-cubes, the teacher walked around in the classroom and commented on their work. The practical work lasted for about 23 minutes. Two minutes were excluded from this lesson part when the teacher gave instructions for working in pairs (social instructions) or asked the pupils to be quiet or to listen.

Communicating scientific content

In the following, ways of communicating the scientific content under the practical work of the lesson are described as; scientific descriptions, scientific explanations and scientific generalizations.

Scientific descriptions

The scientific content in this lesson segment was mainly presented as scientific descriptions. Before the ice-melting children were told to describe the ice-cube. Here the teacher asked the pupils to observe their own ice-cubes.

> E: What shall we write?
> Teacher: You will have to ask your classmate. Hugo and you shall discuss this.
> E: We don't know.
> Teacher: … and give tip-off so to say. How can it be? How does it feel? I cannot say this since it is not my ice-cube. It is yours and Sanna's.

The teacher considered every observation important and every suggestion and idea worth noting. This excerpt clearly illustrates that the pupils did not know what to focus on during their observations.

> Teacher: Write about the ice-cube now, Edward, here before it melts. How does it look? How does it feel? What colour does it have? What form does it have?
> E: Helen, how do I spell "transparency" ? [Swedish: genomskinligt]
> Teacher: Genom-skin-light.
> E: Helen, there is hair in this.
> Teacher: Yes you can write that as well.

When the pupils started to melt the ice-cubes the teacher walked around in the classroom and gave short comments on their activity.

> Teacher: How are you doing?
> E: We warm it.
> Teacher: You warm it. Do you take turns?
> E: Yes.
> Teacher: It gets pretty cold. Has it melted a bit?
> E: Yes.

The pupils described the experiment with short comments like "It is gone!" or "It´s leaking!"

Scientific explanations

> Only once during the practical work one of the pupils tried to explain why the ice was melting.
> E: He is very smart. He ordered me to shake the bag.
> Teacher: Does it work? Will it melt?
> E: I think the molecules will wash over the ice-cube. When the water molecules wash over the ice-cube it will scratch its molecules. But it is not going so fast…
> Teacher: Don't you need? [Another group interrupts the teacher]

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Scientific generalizations

Generalizations were not discussed during the practical work.

In table 4 we summarize the results regarding ways of communicating the scientific content.

Table 4. Ways of communicating the scientific content during the practical work (%).

Scientific descriptions	98
Scientific explanations	2
Scientific generalizations	0

During the practical work, scientific descriptions were the dominating way in which the science content was presented. It was hard for the pupils to know what to look for when describing the ice-cube and the melting process since the teacher took a step back and did not guide the pupils´ attention.

Communicative approach

In the following, the four classes of communicative approach from Scott and Mortimer (2003) is used to analyse the practical work part of the lesson; non-interactive/authoritative communicative approach; interactive/authoritative communicative approach; interactive/dialogic communicative approach and non-interactive/dialogic communicative approach.

Interactive/authoritative communicative approach

Closed questions were often used during the *practical work activity*. The pupils were supposed to fill in a certain word or term. This excerpt shows how the teacher reminded the pupils to make sure that the plastic bags were properly closed.

> Teacher: Now! Now we must, no wait. Somebody here tried to take the ice-cube in advance, but we have to start at the same time. And when you have put in the ice-cube [in the plastic bag], what do you need to check up?
> E: That it is closed.
> Teacher: Yes, you need to check carefully!

The communication during the practical work was clearly interactive since the pupils were part of the conversation. The teacher asked questions to check that everybody was doing something and made short comments whilst walking around in the classroom.

> Teacher: Is that the fastest way do you think?
> E: Yes.
> Teacher: Do you keep it in there?
> E: Yes, inside the clothes.

The pupils didn´t discuss the observations with each other. They just stated what they saw cause melting ice is an experience that they have from everyday life.

E: It´s gone!
Teacher: Is it gone? Look, now it has gone six minutes. Write that down. Now you will start to answer the questions. I write that down. Question three; your answer is six minutes.
E: Ours is gone!
E: Ours is gone!
Teacher: … answer the questions...
E: Ours is gone!
Teacher: Yes.

During the melting the pupils commented on the ice-cube but they were not encouraged to discuss and explore further their ideas. We describe this conversation as an interactive/authoritative communication.

The categorization of communication (Table 5) gives an overview of what kind of communicative approach that is made available during the practical work.

Table 5. Communicative approach expressed as percentage of the total time (21 minutes) of the practical work activity.

	Interactive	Non-interactive
Dialogic	0	0
Authoritative	85	15

During that part of the lesson the teacher as well as the pupils initiated the questions. It was not so evident that the teacher wanted a certain response or answer, she was more concerned that everybody was active and engaged in the experiment.

Discussion

When analysing the empirical material we only found a few examples of explanations and generalizations during these lesson segments which is consistent with the findings of Acher et. al., (2007). We also noticed that the teacher hesitated to engage in scientific explanations. This result is quite the same as the results from Appleton (2002, 2003). He argues that teachers in primary school, often have limited science knowledge and therefore often prefer activities that are fairly safe to manage and predictable in outcome. We think that due to the risk of giving wrong explanations or not knowing all about the phenomena the teacher in this study hesitated. Possibly there is one more reason why there were few examples of explanations and generalizations. Paradoxically a seemingly simple and everyday concept like melting ice can be extra difficult to explain. The starting point in this experiment was an everyday phenomenon that was familiar for all the pupils. Everyone knew that ice melts and it might be hard to find strategies to explain something self-evident. Interestingly, attempts to explain or generalize the transition between different aggregation forms, by use of particle models, were initiated by pupils and were followed by "turning points" (Scott, 2008, p. 32) in the communication to an interactive/dialogic approach.

Scientific descriptions and non-interactive/authoritative and interactive/authoritative communications were most frequently used in this classroom. As far as we can see there are no "good ways" or "bad ways" of communicating. Instead we agree with Scott (2008), stating "…if scientific views are presented in an authoritative way, then time needs to be allowed for the dialogic explorations of those ideas…" (p. 33). However, exploratory talk or interactive/dialogic communication is often considered to play an important role during laboratory activities since it enables the teacher to take account of students´ points of view by the use of effective questions, appropriate wait time

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"and responding with further questions and ideas that are based upon the students´ comments" (Lunetta, Hofstein & Clough, 2007, p. 427; Mortimer & Scott, 2003). However, since much of time in our classroom was spent on instructions there was not so much time left for exploratory talk. Furthermore, the teacher in our study emphasized the need of giving detailed instructions to pupils in grade three to manage such classroom activities (compare Appleton, 2002, 2003).

It was hard for the pupils to know how to discuss and what to observe while they were carrying out the laboratory task. It is not enough to just give pupils the opportunity for discussions, such activities need to be trained (Schoultz & Hultman, 2002). Inquiry-based material is sometimes used as self-instructive and the pupils are supposed to acquire knowledge by themselves (Harlen & Allende, 2006). But if they are left on their own, their talk and activities will not always be productive (Bergqvist & Säljö, 1994; Mercer & Dawes, 2008). If the practical work is supposed to be a link between the empirical/observable and the theoretical/non-observable (Jenkins, 1999; Sjøberg, 2000) the pupils must be given the opportunity to move between those levels with help from a teacher. You can also consider if there are too many aims expressed for inquiry-based learning (Harlen & Allende 2006; Harlen, 2009). It might be hard for the teacher to know how to handle all of them since they sometimes can result in dilemmas or conflicting goals for the lesson (compare Berg, Löfgren & Eriksson, 2007).

Conclusions

By a combination of the categories we can conclude that scientific descriptions were often followed by non-interactive/authoritative or interactive/authoritative communication whereas scientific explanations opened up for exploratory talk. Pupils asked quite difficult questions concerning the movement of the atoms in ice, in the water and during the freezing process. These questions caused turning points in the communicative approach into a more interactive/dialogic approach or exploratory talk in the classroom. Exploratory talk and scientific explanations must be given more attention in the initial teacher training and in the teachers professional development in order to reach some of the goals for inquiry-based science education. However, this may be a challenge for primary science teachers since the scientific content most often is descriptive when taught in primary school. But the teachers also need deeper scientific knowledge so they can and dare stimulate exploratory talk in science education. Teachers play an essential role for the quality of discussion and therefore also the quality of learning.

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