GOTHENBURG STUDIES IN EDUCATIONAL SCIENCES 365

Reasoning in a Science Classroom

Over the past two decades, communication in the science classroom has been the subject of inquiry and discussions. A science classroom is an arena for communication in which several traditions of language use meet and are coordinated: the language of everyday life, of school and of the science disciplines. In this thesis – Reasoning in a Science Classroom – the author analyses a sequence of lessons about biological evolution. The analysis investigates how patterns in the communication develop over these lessons and how these patterns are manifested in the interaction between teacher and students. In light of an increasing emphasis in science curricula on developing students' reasoning skills, this thesis illuminates communicative challenges and evokes questions regarding the consequences for science teaching and learning.

Miranda Rocksén has a broad teaching experience and a background as a science teacher in lower secondary school. This dissertation project was carried out at the University of Gothenburg, and was framed within a collaboration between the Department of Pedagogical, Curricular and Professional Studies and the Linnaeus Centre for Research on Learning, Interaction and Mediated Communication in Contemporary Society (LinCS).

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Abstract

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In research on science education, there is a need to further understand the relation between longer and shorter processes of teaching and learning in the classroom. With a theoretical framework based on dialogical theories of communication, this thesis investigates three aspects of the formation of a science classroom practice: the making of conceptual distinctions, classroom organisations and the making of connections between lessons. The empirical material consists of eleven video recorded lessons on biological evolution in grade 9 (15 year old students). The analysis connects different levels of classroom interaction and patterns in the communication over several lessons as well as the details of particular situations. The empirical findings of the thesis are presented in three studies. The first study shows co-existing meanings of the word explanation and three conversational structures that the teacher used for making distinctions between them. The second study shows how small-group activities are used for coordinating the pace of students' participation in these lessons. The third study shows strategies for link-making and a topic trajectory including questions that were raised in relation to survival and extinction of species. The conclusions point to the significance of coordinating the communication so that patterns such as those described can provide learning opportunities for students.

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PART II
Appended papers

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II. The temporality of participation in school science: Coordination of teacher control and the pace of students' participation

III. A topic trajectory about survival: analysing link-making in a sequence of lessons about evolution

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PART I

1 Introduction

There is a need for new ways of understanding the teaching and learning of science, towards which this project aims to contribute. Research has, using different methodologies, investigated science teaching and learning, in terms of, for example, science teacher strategies, the features of science classroom communication and science classroom activities. What the research in this thesis investigates and makes visible is to a large extent already known by professional science teachers and their students. Although this is a detailed study of only one science classroom practice, there are aspects of it that apply to other science classroom practices too. A number of theoretical and methodological issues have been taken into consideration in the development of a research approach. In this introduction some of the more general considerations and points of departures for this project are presented.

Knowledge, time, teaching and learning

Two issues that have been critical for this project are: how to conceptualise knowledge and learning, and how to investigate the relation between individual events in the classroom and longer processes of teaching and learning. These are critical issues since students are supposed to learn how to correctly apply their knowledge in different situations in the classroom. The importance of including time-dimensions in research for understanding processes of students' knowledge development has been emphasised in the research (Lemke, 2000; Mercer, 2008; Molenaar, 2014). This relates to how to analyse patterns in classroom communication, for instance how a science teacher and students develop specific topics by making conceptual distinctions, make connections between the lessons and participate in activities. Such analysis ought to be conducted on classroom interaction that transcends the individual lesson, and this study is one example. This project demonstrates some relations between the various things that happen in a classroom over several lessons as well as how this is manifested in the details of specific situations. Studies like this have the potential to show empirically

how longer processes in the classroom are influenced by what happens on much shorter timescales.

Research interest

Science teachers and students are co-constructors of the knowledge that constitute school science, for example they apply scientific principles and concepts when solving problems and tasks and repeat issues of specific interest. They use theoretical models and concepts in relation to personal experiences, and they transform them in the interaction, by turning them into metaphors or jokes. The research interest is to establish and understand how patterns of interaction in the classroom are related to the teaching and learning of a science topic.

Teaching and learning about biological evolution

Literature has described many challenges involved in teaching and learning about biological evolution (Smith, 2010b). One challenge is that biological evolution is a topic that involves the use of words that have ambiguous meanings (Rector, Nehm, & Pearl, 2013). *Adaptation* is one example of a word that has different scientific and everyday meanings. In an everyday sense, *adapt* refers to how an individual adjusts to changing conditions in an environment. In the context of biological evolution, the meaning of the word *adapt* refers to a much more complex explanation of survival. More precisely, and in the interpretation of Rector et al., in the context of teaching about biological evolution the meaning of *adapt* refers to "…the process of differential survival and reproduction in a population with heritable trait variations over many generations that produces an increase in trait frequencies that promote survival in that environment compared with that of individuals without the trait…" (Rector et al., 2013, p. 1115). This quote illustrates three of the challenges that the topic of biological evolution creates for teaching and learning: first, the long time perspectives in which differential survival and reproduction work over many generations; second, explanations that include many concepts that may be perceived as just as demanding to understand as the concept explained; third, explanations that include several organisational levels from the genetic level to populations of organisms. The topic of biological evolution touches on worldviews and beliefs, and for some teachers and students and in some religious contexts the topic is controversial (Smith, 2010a).

The communication in science classrooms

The communication in science classrooms has been a focus of interest in the literature (Kress, 2001; Lemke, 1990; Mortimer & Scott, 2003; Ogborn, 1996). As shown by Lemke (1990), the many concepts and models in science curricula are by themselves very complex. Lemke argued that learning science implies learning how to "talk science", meaning how to use the concepts and put them together in thematic patterns appropriate to the science topic at hand. Ogborn (1996) clarified the fundamental role of experimental work in science teachers' explanations of topics in the classroom. The combination of practical demonstrations by the science teacher, students' experimental work and other multimodal classroom activities was in Kress (2001) referred to as "the rhetorics of the science classroom". For Mortimer and Scott (2003), science teaching meant the development of a scientific story in the classroom. They developed a framework with four communicative approaches[1], for the analysis of science teachers' strategies for alternating between modes of giving the correct answers and modes of reasoning and permitting different degrees of student interaction. The four communicative approaches were used by Aguiar, Mortimer, and Scott (2010) to investigate how science teachers respond to students' questions. They showed that in a science classroom where students participate and reason, meanings are continuously negotiated.

Developing a research approach

The current investigation uses a framework based on dialogical theories of communication (Linell, 2009a). This implies a focus on communicative activities during science lessons. The thesis takes the previous research on science classroom communication as one point of departure, and works its way through many considerations made in relation to previous research, theory and methods, finally taking the shape of three research papers with three different focuses. It is hoped that the results will be of interest to all those involved in science teaching and science learning practices, as well as for all those interested in getting an empirical and research perspective on interaction in a science classroom.

[1] The four communicative approaches presented by Mortimer and Scott (2003) are: noninteractive/authoritative, interactive/authoritative, noninteractive/dialogic, interactive/dialogic.

Outline of the thesis

The approach, results and conclusions are described in subsequent chapters. This outline concludes the introduction. Then Chapter 2 (Purpose) describes the aim of this project. In Chapter 3 (Previous research) a look at the origins of two research traditions contributes a historical perspective. Some contrasting conceptualisations are discussed in relation to a number of studies and this creates a frame for the approach taken in this project. Chapter 4 (Theory) presents the theoretical framework and the considerations involved in the methodology, such as three principles that provided a base for the analysis. Chapter 5 (Method) describes both the analytical procedures and how the body of video material was generated. This chapter also discusses ethical considerations, issues of validity and generalisability. In Chapter 6 (Summary of results) the three separate studies are presented and summarised including an overview in table format that briefly presents the purpose, design and main results. Chapter 7 (Discussion) connects the study with previous findings and evaluates the main contributions of the thesis in relation to the purpose. A summary in Swedish follows as a separate chapter (Chapter 8).

2 Purpose

The purpose of this project is *to identify and describe three aspects involved in the formation of a science classroom: the making of conceptual distinctions, classroom organisations, and the making of connections between lessons.* Analysing video recordings from a classroom and making an in-depth study serves this purpose.

The making of conceptual distinctions constitutes an essential aspect of a science classroom and it is assumed that analysing interaction can establish how this is done. Every school subject has its own particular terminology, involving important conceptual distinctions that point out, for example, how to use individual words. For teaching and learning in science subjects, a central task is to make conceptual distinctions, for example, between the many concepts included in the science curricula. This study investigates the making of conceptual distinctions in situations involving the teacher and the students, and how these distinctions are manifested in the communication.

The second aspect of inquiry is science classroom organisations. It is assumed that investigating the organisation of a classroom can establish patterns of classroom interaction, such as students' participation in reasoning. The organisation of classrooms concerns how activities take form, opportunities for students to participate in the classroom activities, and how particular content is sequentially organised. The investigation in this study is focused on how a science classroom practice is organised in order to provide students with opportunities to learn about biological evolution and to participate in such classroom activities.

The third aspect of inquiry is connections between lessons. In the teaching and learning of a school subject, lessons are not isolated units; they are embedded in a schedule and connected to other lessons. The assumption is that the participants in the classroom interaction make connections between lessons and that investigating the patterns in how this is done can reveal how curricular units are constructed.

3 Previous research

This chapter discusses results and perspectives that the literature offers in relation to science classrooms. The intention is to discuss some lines of research, point to some differences among research approaches along these lines and provide the relevant background for the decisions made in the current project.

Introduction

For this project there were lessons to learn from research over a long period of time and from the many directions, theoretical perspectives, and diverging approaches to science teaching and learning in classrooms. There are many possible descriptions of the history of this research. In Ford and Forman (2006), two branches of research on classroom learning are described: studies of teaching effectiveness and studies of language and social interaction, and in Klette (2007) the development of a didactic tradition, with an interest in the teaching of subject matter, and classroom studies, with an interest in interaction and discourse patterns, are described. The idea of this review is to provide a background for the considerations made regarding the design of the current project. This review of previous research reveals contrasting and sometimes conflicting descriptions of science classrooms, which are the result of conceptualisations that have separated some research interests and united other research interests at certain times. The presentation implies a generalisation, and it ought to be noted that what is discussed only applies to some studies and their respective research interests. Studies by researchers with common interests regarding their main epistemological assumptions, research approaches and methods, are here referred to as *traditions*. Two traditions are discussed here: *science education* and *classroom studies*. The two traditions are not easily described or compared and this chapter provides some perspectives on both.

From the position of each tradition, which can be described as paradigmatically different, research has identified aspects considered to be significant for learning opportunities provided to students. Research results

are mainly interpreted in relation to other results within the tradition, and use is made of distinctions, assumptions and language associated with the tradition. It is a gross simplification to describe the two research traditions in terms of dualities such as quantitative/qualitative or normative/descriptive. At the same time, research results about the science classroom practice are communicated using these dualities and others, such as the exploration of knowledge as individual or social, views of learning as acquisition or participation, and the content and context of teaching and learning. The chapter addresses some of these dualities and they are used as headings for structuring the text.

Only a selection of studies and conceptualisations are covered. This selection is based on different criteria. Historical and contemporary perspectives are presented first by referring to various studies. This is followed by a section that discusses epistemological assumptions and methodological approaches. In this section studies are chosen as illustrations of differences among research traditions and approaches. In the third and last section, a strategic selection of studies investigating classroom interaction is presented in order to provide a more comprehensive background for the current project and point to some further possibilities for developing research approaches.

A background

The early development of educational psychology started at the beginning of the 20th century. The problems of education defined the content of this academic discipline, and methods were defined by the science of psychology (Mayer, 1992). At this time, experimental work developed by Edward Thorndike dominated (see, for example, Chance, 1999). Thorndike conducted experiments on animals and formulated a theory of learning based on the idea of stimulus and response. At the same time, taking his point of departure in philosophy, John Dewey conducted developmental work in the University of Chicago Laboratory Schools[2]. In the opening volume of General Science Quarterly, later known as Science Education, Dewey (1916) addressed how, what and why science ought to be included in the education of children. This

[2] A description of the Chicago Laboratory School can be retrieved from http://www.mi-knoll.de/122501.html (Knoll, 2014) and in the Swedish preface to the book Demokrati och utbildning (Dewey, 1999).

can be seen as an early interest in what was later referred to using the broader term *science literacy* (Roberts, 2007), as well as an interest in supportive teaching methods. What Dewey articulated can today be recognised in terms of teachers' *didactical questions*[3], such as: *who* is the presumed learner, *when* and *where* is teaching going to happen, *what* should be taught, *why*, *how* and *when* should something be taught, and *what* is the learner supposed to achieve by this? (cf. Uljens, 1997).

Two traditions

In the second half of the 20th century, teaching and learning in school – and particularly science teaching – was the focus of much research. The number of publications increased and in the late 20th century, there were two main traditions, which overlapped to a certain extent. One group of researchers (science education) studied the teaching and learning of science subjects in school. This research included different theoretical perspectives, but studies were sometimes performed in classrooms (e.g Andersson, 1976). The other group of researchers (classroom studies) looked at classroom interaction and the teaching and learning in classrooms. This research included different theoretical perspectives and approaches, although studies were also performed in the teaching of science subjects (e.g Bergqvist, 1990).

Broadly speaking, research on science education and classroom studies approached teaching and learning from different perspectives and with different research interests. In much research on science education there is an interest for didactical questions and individual conceptions of knowledge has dominated. The Science Curriculum Improvement Study (SCIS) (Karplus, 1964) introduced Piagetian cognitive theories. A significant expansion followed and these theories were the base for characteristic research approaches. The LMN project[4], at the University of Gothenburg was for example influenced by SCIS and developed teaching aids for science in the early years, (see Andersson, 1989). This group was the first research group in Sweden with a science education profile (e.g Andersson & Kärrqvist, 1983). With influential studies, such as Driver and Easley (1978) and Posner, Strike,

[3] Note the different meanings of didactic (see Kansanen, 2002). The etymological original in Greek means: *skilled at teaching, instructive*, *that can be taught,* and as an English adjective, *didactic* means either an instructive purpose for a written piece or a teaching method "that conveys knowledge or information by formal means such as lectures and textbooks, rote learning, etc.". (Didactic, n.d).

[4] LMN: primary and middle years science (original: låg- och mellanstadiets naturvetenskap)

Hewson et al. (1982), research in the science education tradition aimed to improve science teaching by investigating what children had to say about the physical world. In these studies, interviews and surveys were used together with an explanatory model for learning and cognition that is based on the notion of conceptual change. These studies understood children's answers to *why*- and *how*-questions as alternative explanations or preconceptions in relation to the disciplinary explanation of a phenomenon, a method still employed, (see Vosniadou, 2012). The results supported teachers' understandings of topics in the science curricula.

In the tradition of classroom studies, an interest in the social processes in classrooms has dominated. This research concerned classroom life as experienced by teachers and students (Klette, 2007). According to Klette (2007), one influential book was *Life in Classrooms* by Philip Jackson (1990), originally published in 1968. This study stands out for two reasons: the study provided a detailed view of both teacher *and* students; it also introduced both planned and unintended aspects of classroom life. The study used ethnographic observation techniques, which later became characteristic methods in the tradition. Classroom studies established how students' learning was facilitated and supported by verbal interaction and discourse practices (Ford & Forman, 2006; Klette, 2007). The role of initiation-response-evaluation (IRE) sequences in teaching was an early finding described by Sinclair and Coulthard (1975) and Mehan (1979), which is still useful for descriptions of teaching in whole-class (Sahlström, 2008). Bellack, Kliebard, Hyman et al. (1966) found that two thirds of classroom speaking time was used by the teacher, and Cazden (2001) described classroom speaking rights and listening responsibilities. Classroom studies made the teacher's role, the students' roles, and the role of instruction visible. A Swedish example is Bergqvist (1990), who investigated collective classroom activities with students in focus. In the science subjects she showed how a project in optics turned into practical task work, which was carried out by the students but lacked meaning for them.

Traditions revised

Although science education and classroom studies developed as two research traditions, they overlap to an increasing extent. This can be seen in publications that outline the development of science education as a research field (Ford & Forman, 2006; Klette, 2007) and publications that outline this

development through collections of separate and contemporary studies (Schwarz, Dreyfus, & Hershkowitz, 2009). Compared to studies (such as Posner et al., 1982) that describe interview situations and suggest implications for teaching, or studies (such as Mehan, 1979) that investigate classroom interaction seeking to understand the many demands on teachers and students in classrooms, these publications open up new perspectives for a combined interest in the complexities of classroom interaction including the teaching and learning of content. Ford and Forman (2006) present a historical review of science education research and a redefinition of disciplinary learning in the classroom. Klette (2007) suggests that subject matter didactics, one part of which involves an interest in the didactics of science subjects, and classroom studies are merging, a process that enables new understanding about content in relation to instruction. Schwarz et al. (2009) discuss the transformation of knowledge in classroom interaction:

> We chose the term *transformation* for the title of the book to indicate that the changes most of the contributors describe have a historical dimension. Transformation concerns tools as well as individual and collective outcomes. If the English language had permitted it, we would have labelled what we study and are engaged to foster as 'transformation of knowing' (instead of 'transformation of knowledge'). The terms that fuel our quest for tracing and fostering transformation in classroom interaction include *actions*, *shared understanding*, *intersubjectivity*, *argumentation* and especially *succession of activities*. The transformation concerns both the community and the individual; we focus on changes of (communal) practices and of identity.
>
> (Schwarz et al., 2009, p. 2)

It is noticeable how the studies included in the book are described as going from passive to active, from individual to individual *and* collective. The changes are summarised as a transition from 'knowledge' to 'knowing', emphasising knowledge as actively and socially constructed (and transformed). This provides evolving opportunities for discussing the contributions from different and contrasting conceptualisations of knowledge and of learning, in order to better understand contemporary conditions for teaching and learning in school.

Contrasting conceptualisations

Knowledge as individual and social

Research about teaching and learning is based on epistemological assumptions. Kelly, McDonald, and Wickman (2012) identify three conceptualisations of epistemology represented in science education: the disciplinary perspective, the personal ways of knowing perspective, and the social practice perspective. The disciplinary perspective represents the ways that the history of science and philosophy of science has informed ideas of learning, for example with regard to theory change and what to include in science curricula. The personal ways of knowing represents psychological perspectives on individual learners' conceptualised knowledge, for example, theories about children's alternative explanations for natural phenomena. The social practice perspective examines how members of an epistemic culture define knowledge locally in processes of negotiation. Kelly et al. underline that the social practice view on epistemology includes a great variation, from relativist positions to the study of students' use of evidence. Knowledge seen as individual and knowledge seen as social are traditionally two contrasting conceptualisations that have major consequences for approaches developed within research, on methods used, how results are interpreted, and for views on teaching and learning more generally.

Much research within the science education tradition has been conducted based on assumptions of knowledge as individual cognitive entities (van Eijck, 2012). For example, the main interest for the theory of conceptual change was the individual and individual processes of thought: "When will individuals find it reasonable to undertake a major reorganization of their current concepts or to replace one set of central concepts with another?" (Posner et al., 1982, p. 213). The quote indicates an intention to look for an explanatory model and articulates an interest in cognitive mechanisms involved in the individual's learning. It describes an 'input–output' model of teaching and learning. Epistemological perspectives in the science education research tradition, for example, knowledge conceptualised as an individual entity, have repeatedly been subjected to critique (Jakobsson, Mäkitalo, & Säljö, 2009; Schoultz, Säljö, & Wyndhamn, 2001; Solomon, 1987, 1994).

Methodological critique - one example

One study that articulates methodological critique is Jakobsson et al. (2009). The different conceptualisations of knowledge are made clear when the authors critique individual (and constructivist) conceptualisations of knowing by scrutinising another study (i.e Andersson & Wallin, 2000). This is an illustration of how research tends to argue for one side of the duality: knowledge as individual/knowledge as social. According to Jakobsson et al., research has reported "…a rich array of 'misconceptions'…" (Jakobsson et al., 2009, p. 980) in the area of global warming and the greenhouse effect. In their study of group discussions about climate change, they find that students develop thematic patterns that are appropriate for a more scientific language use and claim that this questions the previous findings. Andersson and Wallin (2000) is based on a survey with responses from about 300 students in each of the three grades 5, 9 and 12. In the written responses to questions, Andersson and Wallin find five ways in which students explain and discuss the green house effect.

One way to understand Jakobsson et al. (2009) is as an epistemological critique of assumptions in the approach to empirical material. The contrasting conceptualisations in relation to the different studies and their purposes shows that each of the two approaches can be seen as relevant for the investigation of their respective empirical material. What Jakobsson et al. use is an approach that can be considered as appropriate for answering questions like: *What is happening in group discussions about climate change?* Andersson et al. (2000) use an approach that can be considered to be appropriate for answering questions like: *Is there a systematic effect in written answers to test-questions about climate change?* For a discussion about types of research questions (see Ercikan & Roth, 2006). One problem with the study by Andersson and Wallin is that if it is adjusted to investigate aspects of written answers to questions, the relevancy of discussing relations between them and students' thinking requires a theoretical motivation. Based on this the theoretical platform provided can be questioned and motivates a critique that addresses lack of coherence.

Another way to understand the critique is as a critique on the epistemological perspectives that assessment practices more generally are based on. This is in fact what Jakobsson et al. (2009) ask for: pedagogically meaningful ways of studying knowing about complex issues such as climate

change. The problem with this critique is the conceptualisation of knowledge and learning in the pedagogical practice. Stating: "Knowing should be studied in action" (Jakobsson et al., 2009, p. 993) based on a study of group discussions ranging over parts of lessons means delimiting the view of knowledge and learning in the pedagogical practice. Pedagogically meaningful ways of studying knowing about complex issues requires a conceptualisation of the pedagogical practice that includes many timescales. Conceptualisations that include knowledge and learning as individual and social temporal events enables the examination of several activities in many time-dimensions of classroom practices (Molenaar, 2014).

Knowledge in a science classroom practice

There are strong arguments for understanding classroom practices as including various activities (teaching, learning and assessment) and for the idea that knowledge takes different forms depending on the activity. Understanding group discussions and written answers to questions (and large-scale testing) in combination, would provide a way of getting around blunt comparisons between different activities in a professional practice. This does not mean that every methodological critique is unwarranted. The individual conceptions of knowledge and emphasis on communication as information transmission are positions whose adequacy can be contested for the study of classroom interaction.

On the one hand, the contrasting conceptualisations of knowledge and the strong argumentation around it illuminate how seeing the individual student in relation to a group of students is important for understanding teaching and learning in a classroom practice. On the other hand, the methodological critique is shown to concern more than research methodology and pedagogical practice. Historical circumstances behind the methodological criticism of science education can be traced back to the main assumptions of the early research on learning (Cobb & Bowers, 1999).

One perspective on the individual student as a participant in the evolution of classroom practices is presented by Cobb and Bowers (1999). The classroom practice is here seen as a communal micro-culture co-constructed by the participating students and teacher. It is a perspective that conceptualises knowledge as individual *and* social. Based on this perspective, research may ask questions that are appropriate for capturing and analysing different situations where students participate and where knowledge is used in

relation to the practice and its evolving participation frameworks, such as, for example, participating in discussions and responding to written test questions. In the study of science classrooms this perspective is useful. Maths classrooms, as studied by Cobb and Bowers, and science classrooms are arenas where distinctions between knowledge as individual or social play important roles, which the science education literature about argumentation shows, as described in a later section.

Acquisition and participation

For educational research, understanding learning is a central issue. For a study like this, aiming to describe aspects of the practice, the views on learning, knowledge, content, and context are related and influence such things as research design and units of analysis. For investigations based on assumptions of learning as acquisition as well as investigations of assumptions of learning as participation in practices, different units of analysis are relevant.

Learning described in terms of changing participation in practices and learning described in terms of acquisition have been summarised in two distinct metaphors of learning: the *acquisition* and *participation* metaphors (Sfard, 1998). The article by Sfard is frequently referred to and has influenced many discussions about learning, and therefore these two metaphors are presented next and illustrated by a couple of studies. The problem with metaphors is, as a later text by Sfard suggests (Sfard, 2008), that the use of metaphors is what remains when clear definitions are lacking.

Metaphors of learning

It was Sfard (1998) that introduced the two metaphors, acquisition and participation, in relation to theories of learning. The two metaphors articulated two distinct and contrasting conceptualisations of learning without excluding one of them. The acquisition metaphor means a view of the learner and human mind as more or less a container. Learning means filling this container with knowledge. This understanding of learning emphasises the role of communication as information transmission. This is implied in research approaches that for different reasons make assumptions about the process, for example, those approaches that take the purposes and common goal behind communication for granted. The participation metaphor, on the other hand, involves a learner participating in practices. The participation metaphor

implies an understanding of learning as an apprenticeship and as involving changing patterns of participation. Learning seen as apprenticeship emphasises communication as participation. This is a consequence of research approaches that make assumptions about the process as part of the learning goal, for example, those approaches that take communication as an indicator of participation in a community.

The acquisition and participation metaphors of learning originate in cognitive theories. Cobb and Bowers (1999) describe two waves of a cognitive revolution. The first wave was concerned with individual perspectives on cognition, and the social and collective aspects of learning situations became the concern for the second wave. Ludvigsen (2009) describes cognition on different levels: the study of individual knowledge construction in social activities represents the level of ontogenesis; the study of knowledge constructions in interaction and conversation represents the level of microgenesis, and the study of historically developed knowledge represents the level of sociogenesis. Hakkarainen and Paavola (2009) suggest a knowledge-creation metaphor and claim that this requires a trialogic approach to learning. A trialogic approach to learning takes into account learning as purposeful innovation and focuses on the collaborative development of mediating objects or artefacts.

Three studies for illustration

The three studies discussed next are chosen to illustrate how assumptions regarding learning give rise to contrasting empirical approaches and are manifestations of the acquisition and participation metaphors in science education research. One illustration of the acquisition metaphor is Mikkilä-Erdmann (2001). This is a study based on the theory of conceptual change that investigates the relation between text design and student reading comprehension of photosynthesis. By developing instructional texts and demonstrating improved test results, this study seeks to foster children's metaconceptual awareness and construction of a mental model of photosynthesis. A second illustration is Harrison and Treagust (1996), who use interviews to present the mental models about atoms and molecules that are held by a group of secondary students. Harrison and Treagust suggest that working with multiple models might improve instruction by moving towards process-driven explanations but the methodological approach implicates a view on communication as peripheral. Both studies are focused on the

individual and use research methods of evaluative characters that treat other aspects of the situation, such as for example communication and purposes of the tasks, as unproblematic. In these approaches it is assumed that the pre- and post-tests in Mikkilä-Erdmann and the exchanges during interviews in Harrison and Treagust are evidence of students' cognitive performances. A contrasting study and illustration of the participation metaphor is Roth and Lee (2004). In this study a school project about environmental issues in a nearby creek is studied, focusing on the communication in the process. This study analyses students' own interviews and conversations with representatives from the nearby community and with parents during an open-house event where students present their work. The assumption is that students' communicative processes are part of the learning goal and the research approach is developed in order to capture these aspects of the situations. Hakkarainen and Paavola (2009) point out that in many cases studies are limited to the investigation of performance or prevailing cultural practices, and the three studies above are an illustration of this.

For the current project, the metaphors of learning imply alternative views on the communication that takes place in the classroom, and this has consequences for the research design developed here. In this project, the investigation of a classroom practice acknowledges teaching as a temporal process and locates learning in evolving participation frameworks. This means that this research focuses on situations that in different ways shed light on the conditions for learning rather than on situations that evidence learning. This is discussed in terms of how classroom organisation allows evolving participation frameworks, how the making of conceptual distinctions is enabled in the communication, and how the teacher and students facilitate connections between lessons.

Product and process

The practice turn

What have been described as more traditional science education research and classroom studies today coexist with, for instance, research approaches evolving from 'the practice turn'. In the historical development of research approaches on learning, the 'practice turn' was important (Ford & Forman, 2006). The expression refers to a shift from *process-product* research in terms of methodologies focusing on teacher behaviour and student outcomes ('input-

output'), towards *context-process* research, focusing on how learning occurs in the classroom (Ford & Forman, 2006).

Process-product approaches follow from the rationale that research is about establishing causal relations, which was typically expressed in the ideas of stimulus and response (Chance, 1999). Finding a causal mechanism was also the rationale behind the conceptual change theory (Kelly et al., 2012). For instance, Hewson and Hewson (1984) focus on the relation between instructional design and what are conceptualised as students' cognitive conflicts. In contrast to this, context-process approaches reoriented the research towards people's activities and the social context or, as Cobb and Bowers (1999) put it, situated views of learning position the physical location of context with regard to the world of social affairs.

The situated views on science teaching and learning provided by context-process approaches give insight into a multitude of processes involved in science classroom practices. They open the door to the activities that are performed in classrooms, to the various actions that are taken by individuals and to the communication about science topics in these situations. They provide conclusions that are situated locally; however finding relevant generalisations is maybe more difficult. Ford and Forman (2006) state that an increasing number of microethnographic studies enable descriptions of how science is learned but not what students bring with them. This suggests that the microperspective is not sufficient in order to understand learning as something that goes on over longer time spans. Next, two studies that exemplify situated views of science classrooms are briefly presented.

Examples of situated views

Bianchini (1997) and Kelly and Brown (2003) investigate students' communication during small-group task-work. Bianchini finds that students working in small-groups in a unit about the circulatory system rarely move beyond observational and procedural talk, that students with perceived academic ability and popularity have greater access to physical and linguistic resources, and that students make few connections among school, science and everyday life. Kelly and Brown find that when students participate in cycles of design, presentation and production of solar devices, they negotiate ways of accomplishing the task, present ideas and products to multiple audiences, and distribute credit among the members in the group.

Students' actions in these situations are described and analysed in some detail but the descriptions are not oriented towards the performance or participation in a prevailing cultural practice, as described previously. Instead, the descriptions offer insight into students' different achievements during small-group task-work. This analytic perspective is a contrast to analytical perspectives in so-called process-product approaches. Process-product approaches treat the teaching and learning situation as if it is a black box not open for study. At the same time, the limitations of the context-process approaches, as they are described here, are that they only provide insight into certain situations without taking into account the longer teaching and learning processes of which they are part. In the present project, the interest is to understand on-going activities and how the participants orient the communication to the science subject in the classroom over several lessons.

Content and context

The two words *content* and *context* recur frequently in this discussion. These two words represent how research in fact conceptualises very differently what might seem to be similar. Conceptions of knowledge and learning have consequences for perspectives on content in teaching and learning as well as for perspectives on context – and vice versa. One view on context implies viewing school as one context for learning, as opposed to an out-of-school context or an everyday context for learning (see Braund & Reiss, 2006; Rennie, Feher, Dierking et al., 2003). Another view on context implies taking into account students' meaning-making in the context of a teaching situation. For example, when Gilbert (2006) interprets context, he provides a perspective on how to support students' making of meaning in chemistry education: "When a context provides a coherent structural meaning for the students /…/ it can be expected that the personal relevance for the students will be related to an understanding of why they are learning about chemistry" (Gilbert, 2006, p 962). This view on context together with assumptions about the benefits of contextualised science teaching is recurrently addressed in the science education literature. Another view on context is represented in Duranti and Goodwin (1992). Context in this view relates to speech production: the way that talk itself provides context as well as invoking new context. For an analysis this implies taking into account the small signs in spoken language such as for example prosody, pausing and hesitation,

overlapping speech and choices of lexical forms. These conceptualisations of context are only three in a range of possible research positions: from treating science content as objective facts physically located in a specific classroom context or everyday context and transferred between such contexts, to treating science content as physically located in a context consisting only of discourse patterns.

Research in science education has a unified interest in understanding the relations between science content, science teaching, and science learning. However, this multifaceted research includes many theoretical perspectives and methodological approaches (see Fraser, Tobin, & McRobbie, 2012), and many different definitions of what, for example, science content means. Classroom communication is, for example, the focal point for a multitude of interests. For this study the heterogeneous literature on argumentation in science education illustrates various distinctions regarding content, which are used in investigations of science classroom communication. It illuminates the need for other more useful terms than *science content* in attempting to understand what is at stake during the reasoning and argumentation in a science classroom.

One illustration: literature about argumentation

Argumentation was introduced as a significant aspect of science teaching and learning by Kuhn (1993). By investigating scientific and argumentative thinking, Kuhn showed that interpreting data in terms of evidence and providing an explanation are important steps in children's development as well as for the development of the scientific argument. Driver, Newton, and Osborne (2000) took the discussion further by considering how the social construction of scientific knowledge might be applied in science teaching. They agreed that argumentation is central for the interpretation of empirical data and that taking part in processes similar to scientific ones ought to be essential for any education about science. The two publications describe argumentation as teaching content, and theoretical definitions of this content are suggested by Driver et al. (2000).

Today, the literature about argumentation has developed along three main lines: teaching about argumentation patterns, socioscientific issues, and students' learning through argumentation. Literature along the first line argues the essential role of argumentation as content in science learning by promoting teaching about the Toulmin argumentation pattern (Erduran,

Simon, & Osborne, 2004; Simon, Erduran, & Osborne, 2006). Second, literature about socioscientific issues views argumentation as a medium for learning about science topics in various (societal) contexts and develops certain teaching and learning activities to support this (Ratcliffe, 1997; Sadler, 2004, 2009). There is also literature that approaches argumentation in classrooms as empirical material suitable for analysis of discourse patterns used in students' processes of learning specific topics in science curricula, for example genetics (Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Zohar & Nemet, 2002).

The multiple conceptualisations of what argumentation (and explanation) mean in the science education context can also be seen in a few other publications (Berland & McNeill, 2012; Berland & Reiser, 2009; Braaten & Windschitl, 2011; Osborne & Patterson, 2011) that illustrate how the literature continuously develops different definitions and conceptualisations of content and context.

Normativity

Normativity in research may be discussed as a matter of degree and direction. The science education research tradition has a normative tendency and so has the tradition of classroom studies. If normativity is discussed as a matter of degree, this means the extent to which a research study expresses views on how teaching and learning ought to proceed. There are for example learning studies that are designed for the purposes of developing teaching about a limited selection of content (see Holmqvist, 2011), and design-based research that evaluates longer teaching interventions using pre- and post-tests (see West, 2011). There is also research that talks more generally about such things as productive disciplinary engagement in classrooms (see Engle & Conant, 2002). All these examples are clearly normative with regard to the classroom practice although to different extents.

If normativity is discussed as a matter of direction, this means prescribing teachers' or students' actions in a classroom practice. In science education, normativity is almost a presumption that unites many otherwise contrasting approaches. This is a consequence of the focus on and interest in providing answers to teachers' questions, described previously. If research provides answers to questions such as: *What should* be taught? *Why, how* and *when should* something be taught? these answers are directed to teachers and are to some

extent prescriptive. There is also a point to be made about the relevance of suggested implications for teaching. For instance, implications from studies investigating individual conceptions of knowledge do not always account for the complexities of the teaching situation, and the relevance of these implications can therefore be questioned. In classroom studies there are other normative claims about preferred instructional strategies. Some studies were concerned with the student perspective and took an interest in discourse patterns in classrooms. From this a whole literature concerned with supporting dialogic teaching, dialogic learning and dialogic classroom communication has followed (Lyle, 2008; Mercer & Howe, 2012; Sarid, 2012). Normativity is here understood as existing on the line between prescription and description.

Further queries

This chapter started by describing the development of two traditions: science education and classroom studies. It took a historical and chronological approach to some early North-American initiatives and more recent developments, and discussed some contrasting conceptualisations that have dominated. This gave a rough orientation in a dynamic of different assumptions regarding knowledge, learning, content and context. This last section suggests further possibilities for understanding and designing research about science teaching and learning using other conceptualisations and distinctions. A selection of different approaches to the investigation of science classroom interaction is presented. The headings in this section are in the form of themes and point to some of the analytical concepts used in the different studies.

Temporality

Emergent processes and multiple scales

The absence of time-dimensions is a significant limitation for classroom research (Lemke, 2000; Mercer, 2008; Roth, Tobin, & Ritchie, 2008) and conceptualisations of learning increasingly include dimensions of time (Molenaar, 2014). Time is a resource that has a significant influence on the conditions for learning in classrooms; it is through distinct time units, such as starts and ends of lessons, the school day, and the semester, that classroom

practices are delimited. For investigations of classrooms, time-dimensions are important and one interesting possibility is to focus on interaction between adjacent timescales, as suggested by Lemke (2000).

Lemke (2000) shows how education, teaching, and cognitive processes develop on different timescales. Using this model, the empirical material that is used in educational research can be classified in relation to reference events such as thematic unit, school day, lesson sequence, lesson, episode, exchange, and individual utterances or words. For example, the 'context-process' approaches, described in the previous section, typically investigate *episodes*, one reference event on the scale, and the 'process-product' approaches typically investigate differences in test-results in two instances before and after one reference event, such as before and after a *lesson* or before and after a *lesson sequence*. The timescale presented by Lemke can also be understood as a description of all those simultaneous processes that each investigated moment is part of. According to Lemke, focusing on the interaction between adjacent scales, such as, for example, the use of an individual word in a dialogue exchange or an episode, in relation to a lesson, enables research to identify and describe the processes where new scales are emerging. Such emergent processes in classrooms are, for example, new routines, particular jokes, informal rituals, and favourite word usages with special meanings.

Studies – although with different emphases and theoretical assumptions – point to dimensions of time as important in classroom research, for instance for investigating continuity (Bloome, Beierle, Grigorenko et al., 2009; Engle, 2006; Scott, Mortimer, & Ametller, 2011; Tiberghien & Malkoun, 2009; Ødegaard & Klette, 2012). In the empirical studies, diverging methods are used. For example, in Bloome et al. (2009), the view on time relates not only to quantitative but also qualitative processes, understood as how teacher and students construct relationships between units of time on different scales, for example between different lessons or over the academic year. A study that takes a conceptual approach using three scales in a science classroom is Tiberghien and Malkoun (2009). They represent the teaching sequence on the macroscopic scale, the theme in the school subject on the mesoscopic scale, and the epistemic task and facet on the microscopic scale. A contrast is Sahlström and Lindblad (1998), which illuminates how two students' science lessons about magnetic fields are related to the construction(s) of their school careers. Ways of coding and levels of analysis are discussed by Ødegaard and Klette (2012) and they develop an approach based on the idea of investigating

adjacent timescales (Lemke, 2000). Their analysis of actors, conceptual categories and levels focuses specifically on instructional format on the macro-level, classroom discourse on the meso-level, and features of language use on the micro-level, combining categories from two coding systems.

Science classroom communication

Epistemological moves and communicative approaches

Some investigations of science teaching as communication describe communicative strategies and tools used in science teaching. The analysis of epistemological moves (Lidar, Lundqvist, & Östman, 2006; Lundqvist, Almqvist, & Östman, 2012) investigates communicative strategies for socialising students into school science; the construction and critique framework (Ford, 2008; Ford & Forman, 2006) redefines the science classroom in terms of being a communicative practice, and the communicative approach framework (Aguiar et al., 2010; Mortimer & Scott, 2003; Scott, Mortimer, & Aguiar, 2006) characterises the talk during school science lessons.

Lidar et al. (2006) show how the teacher, in encountering students' meaning-making activities, continuously secures institutional aspects of the practice by establishing epistemological norms. For example, the question "And when does this boil?" (Lidar et al., 2006, p. 153) is understood as a *confirming move* because the teacher by asking this question confirms that the students are doing a valid experiment. This approach is used by Lundqvist et al. (2012) for comparing one teacher's epistemological moves with ways of teaching and selective teaching traditions. In the framework by Ford and Forman (2006), the scientific practice is seen as an interplay of roles: those who construct and those who critique claims, with the science classroom reflecting this practice. Ford and Wargo (2012) designate teachers' discursive operations while lecturing on five levels: *nonact*, *recount*, *explain*, *juxtapose* and *evaluate*. Mortimer and Scott (2003) introduce the idea of a speech genre of the school science lesson. In order to characterise the talk during science lessons, they first develop a quadrant of four possible communicative approaches and then include them in an analytical framework. This framework is used by Scott et al. (2006) to identify key features of authoritative discourse and dialogic discourse, by Aguiar et al. (2010) to investigate the relation between

students' questions and these discourses, and by Lehesvuori, Viiri, Rasku-Puttonen et al. (2013) to code and compare patterns from different lecturers.

The idea of providing a flexible characterisation of a school science lesson speech genre is interesting. Nevertheless, the four communicative approaches by Mortimer and Scott (2003) restrict the view on what goes on in a classroom. To be able to capture the dynamic and the multitude of variants of science teaching, a less instrumental framework would be useful: a flexible framework that makes it possible to distinguish the different aspects that are significant in science classroom communication.

Science classroom activities

Interactional moves and artefacts

Currently, research approaches combine and develop frameworks in order to investigate how patterns in classroom interaction relate to the teaching and learning of science content (Roth, 2010). A field emerges that exhibits a variety of research interests and definitions of the study object. Studies, such as the ones presented next, approach the communicative and cognitive dimension of science classroom activities by focusing on individual actions and developing conceptualisations of the interactional moves (both interpersonal and conceptual) that are situated in the communicative context.

Krange (2007) shows the phases in which participants in moment-to-moment interactions, mediated by artefacts, attend to aspects of content to solve the learning task. This analysis conceptualises interpersonal relations in terms of *authorizing*, *problematizing* and *accountability,* conceptualises conceptual practices such as *bridging*, *transcribing* and *filling,* and conceptualises interactional moves as *free* or *forced* depending on whether it is necessary to carry out these moves in order to be able to solve the problem. Kaartinen and Kumpulainen (2002) is another example of a study that investigates the mechanisms of explanation-building based on small-groups that are discussing solubility in chemistry. They establish the distribution of different moves among the participating students: *discourse moves*, *logical processes*, *nature of explanation,* and *cognitive strategies*. Another approach is represented by Wickman and Östman (2002), who investigate learning as discourse change during students' work with insects in a practical activity. They analyse students' practical epistemologies in terms of how students in *encounters* identify *gaps* and establish difference and similarity *relations* to what *stands fast*. Xu and Clarke (2012)

investigate a physics lesson involving the activity: construction of a pendulum. They argue that the language of science is an artefact, that the meaning emerges in the course of coordinating action, and they map how students use *conceptual artefacts* such as, for instance, reference point, variable, and friction, and *physical artefacts* such as, for instance, scissors, clamp and stopwatch.

Another approach to the communicative and cognitive dimension of classroom activities is to investigate cognitive practices (Bloome et al., 2009). A cognitive practice is viewed as a situation-specific set of particular and shared cognitive practices that the student is supposed to employ by taking part in the teaching of a school subject. For Bloome et al. (2009), who study a language arts classroom, this implies for example that students are supposed to compare current reading material to previously read material by retrieval, comparison and contrast, and synthesis. Thus, a cognitive practice involves a multiplicity of processes, which students receive instruction about and carry out in the classroom. For a science classroom, a corresponding characterisation would include, for example, descriptions of how typical activities are composed, how science topics are connected into curricular units, as well as the possibility of comparing variants of science classrooms.

The above-mentioned studies are facilitated by detailed documentation of student interaction during activities, a prerequisite for answering questions regarding how patterns in the interaction relate to the teaching and learning of science content.

Summing up

This review of previous literature in science education, learning sciences and classroom interaction started by mentioning the two traditions of science education and classroom studies and some contrasting conceptualisations. The last section drew conclusions based on previous research in terms of further possibilities for inquiry. The conclusions were that it would be worthwhile to include time-dimensions in research approaches, to conceptualise science teaching as a communicative activity, and to investigate mutually communicative and cognitive science classroom activities.

The review shows that the extensive literature on science education and science classrooms has not yet provided the relevant multi-scale descriptions of how patterns in classroom interaction relate to the teaching and learning of particular content. This is therefore of great interest for the present project.

4 Theory

In this chapter the theoretical and methodological background to the project is described. First, dialogical theories of communication are presented more generally. Second, some analytical approaches to science classrooms based on dialogical theories are presented. The final part describes how dialogical theories are applied in the project.

Dialogical theories of communication

General presentation

Dialogical theory, or dialogism (Linell, 1995, 2009a), is an inclusive framework for analysing communication. It is inclusive because it represents a variety of compatible theories with a long tradition in the human sciences. Dialogical theories share assumptions about the dialogical nature of human action, communication and mind, across analytical approaches and disciplines. For the analysis of spoken language, there are many possible analytical approaches that share these same broad assumptions and influences. Some examples are conversation analysis (Sacks, Schegloff, & Jefferson, 1974), the analysis of activity types (Levinson, 1979), and interaction analysis (Jordan & Henderson, 1995). In the science education field, dialogical theories offer distinct alternatives to cognitive theories for the analysis of classroom interaction. This is something that has been asked for in the science education literature, for example by Roth (2010), who emphasises the need for multiple frameworks, sociological and psychological, in order to be able to understand the complexities of science learning.

This project, and the theoretical background presented here, represents one possible interpretation of dialogical theories. There are a broad variety of other applications of these theories in educational research, some of which provide ideas for best teaching practices, for example by promoting certain forms of *dialogic* classroom communication (Mercer & Howe, 2012) or certain forms of *dialogic* teaching (Lyle, 2008). It should be noted, however, that the dialogic theory or framework that is presented here does not promote any

particular instructional strategies for classrooms. Instead, it represents a state of thinking about "language, mind and world" (Linell, 2009a), for instance in relation to communicative activities that are carried out in classrooms.

For this project, a dialogic framework provides the necessary distinctions, assumptions and methodological approach to the empirical material. According to Merriam (2009), this is basically the role of theory for research. It is a deliberate choice to develop a framework based primarily on the writings of Linell (1995, 1998, 2009a). This restriction is convenient and the framework allows for breadth in interpretations. Linell's dialogism brings together dialogical theories of communication in the human sciences, from such disciplines as philosophy, literary theory, psychology, sociology, and education (2009a, pp. 402-403). One of the main influences is the work of Mikhail Bakhtin (1895 – 1975), who wrote about dialogue and spoken discourse in literature (Bakhtin, 1981, 1986). The project is developed in a reciprocal process of reading and writing about the theory and particularly the dialogical principles that constitute its core.

Dialogism and monologism

Dialogism and monologism belong to different cross-disciplinary paradigms. Dialogism emphasises the dialogic character of language, which is most apparent in verbal communication. According to Linell (2012), what characterises spoken language differs in many ways from the form and logic of written language, and it is important to take these differences into account in analysis. One of the things that characterises spoken language is *the sequential production of utterances,* meaning that spoken language is produced piece by piece: it is not a final product. A second characteristic is that spoken language is *embodied,* meaning that it is (often) produced face-to-face and, for example, involves gestures and intonation: it is not an artefact. A third characteristic is how linguistic resources, like words, have *meaning potentials:* word meaning is not definite and language is not a rule system but a toolkit of constructions. These fundamental differences are essential and recognised particularly in the analysis of communication, both as short exchanges between individuals and as human communication in a broad sense. In his dialogism, Linell (2009a) encourages the rethinking of language, mind and world, and the building of a theory of human mind founded in communication. The emphasis on language as social, dynamic and contextual is not compatible with product-centred,

individual models of perfect communication. Dialogism takes a counter position to *monologic theories* about cognition and the mind.

Monologism is an epistemology that has a long history in philosophy and other sciences, where it represents the dominant paradigm. Linell (1995) summarises monologism using three theories: *information processing theory*, *the transfer theory of communication* and *the code model of language*. First, the information processing theory is represented from cognitive perspectives, for example in psychology. Human cognition is viewed as information processing, or the processing of internal symbolic representations of the environment. This input-output model is applicable also to views of learning as internalisations and memory as storage. Second, the transfer theory of communication, or "*transfer-and-exchange model of communication*" (1995, p. 22), based on the speaker's intentions, views the individual speaker as the single interpreter of the meaning of an utterance. The speaker transfers information to the listener, like a transportation chain. The task of the listener is to understand the information in accordance with the speaker's intentions. This is an individualistic approach to and treatment of communication from one sender to one recipient. Third, the code model of language structure means that language is based on a certain logic that precedes the use of language. For example, it includes certain words with a fixed meaning, and sets of words are composed into sentences whose meaning is derived from the grammatical composition of these words. Linell (1995) explains the dominant role of monologism as being due to the role of written language in our cultural history. It is the written language that has provided a model for views on language as a whole, as well as being the medium for its description. Contrary to monologism, dialogism emphasises that language is dynamic, and that cognition and communication are processes of interaction with the physical and social environment.

Dialogical principles

Dialogism as a paradigm embraces theories on sociality, interaction and communication, primarily dealing with the human mind (Bakhtin, 1981, 1986; Linell, 2009b). Dialogical theories explain meaning-making as other-interdependent, interactive, contextual and multi-voiced. Thinking and communication are embedded in activities such as writing, talking and reading. *Dialogue* is used not only to designate concrete events involving two parties

talking to each other. In an abstract and metaphorical sense, dialogue is used as a designation for any kind of human sense making. *Dialogicality* can therefore be seen as a property of the subject matter under study (Linell, 2009a). As an epistemological framework, dialogism provides a rationale for how human beings generally make sense of the world in a way that systematically takes dialogicality into consideration. Based on a set of shared assumptions, dialogical theories of communication deny the idea of perfect communication between a sender and receiver (Linell, 2009a, 2012). Individual utterances are constituted by and make participants responsible for talk-in-interaction and can be understood by means of three dialogical principles: *act-activity interdependence*, *sequentiality* and *joint construction* (Linell, 1995, 2009a). The principle of act-activity interdependence states that individual utterances are embedded in the activities of which they are part and that the utterance and activity are mutually defined. Sequentiality of an utterance implies that the meaning is partly constituted by the position of an utterance in the context of other utterances: the temporality of real-time interaction. The principle of joint construction states that the participants in a dialogue coordinate their interactions into a joint accomplishment. Dialogical theory is contained within these working principles. For the framework in this particular project, the three dialogical principles, *act-activity interdependence*, *sequentiality* and *joint construction*, are used in the methodological approaches, with a different principle in focus in each of the papers. In the analytic work, the principles are turned into tools that allow the unwinding of a sample of spoken discourse.

Applications of the theory in research

Dialogical theories provide a number of possible analytical approaches. On the one hand the theories allow the analysis of science teaching and learning as meaning-making activities. On the other hand the theories allow the analysis of science lessons as a type of communicative activity with several empirical dimensions. Both analytical entry points are exemplified below.

Studying meaning making in the classroom

Studying meaning-making is a way to investigate the dialogical nature of learning in processes of interaction with physical and social environments. The study of learning as meaning-making implies focusing on the building of

relations such as: I/other, text/context, time/space. In the context of science classrooms, Ford (2008) and Forman and Ford (2014) create a model of learning science as construction and critique, which reflects the idea of the I/other relationship. Instead of highlighting the *authority* to construct scientific claims, this model emphasises knowledge about how claims are held *accountable*. Krange and Arnseth (2012) is another example that conceptualises shifts between conceptual and procedural orientations that are *responsive* to the contextual aspects of doing school science. *Intertextuality* conceptualises the building of relations between texts or between text and context, for example textual and material links, hands-on explorations, and the recounting of events (Kumpulainen, Vasama, & Kangassalo, 2003; Varelas & Pappas, 2006; Varelas, Pappas, & Rife, 2006). Others develop the idea of *hybridity* by using the concept of *third space* to denote how knowledge and discourses from different spaces merge (Gutiérrez, Baquedano–López, & Tejeda, 1999; Moje, Ciechanowski, Kramer et al., 2004). Furberg and Ludvigsen (2008) take into account how *continuity* and *change* are constructed and thereby focus on the building of relations between time and space. These are examples of how learning as meaning-making is conceptualised as the building of different relations in the science classroom context. In that sense, the selection represents dialogical research approaches with an interest in science teaching and learning.

Some studies that investigate learning as meaning-making do not use the dialogical perspective only for understanding meaning-making processes but also for drawing conclusions about how learning (and teaching) ought to be performed or organised. For example when Wegerif (2008) describes a dialogical approach to the study of learning, he says that this implies studying how students learn to see things from two perspectives at once, their own perspective and the teacher's perspective (Wegerif, 2008, p. 353). However, for an analytical approach this implies a restriction. Investigating how students learn to see things from at least two perspectives does not effectively capture the complexities of meaning-making as the building of relations. Rather, this illustrates a search for one outcome that might lead to conclusions about how teaching ought to be organised in order to best suit the situation. The philosophical and historical roots for literature pertaining to a "*dialogical education"* are put together by Sarid (2012). For the study of dialogicality it is relevant to study meaning-making activities, but this does not necessarily mean studying only how students learn to see things from two perspectives.

Instead, the building of relations through interaction with the physical and social environment, in different directions and dimensions, can be studied as ongoing processes of human sense making.

Studying a communicative activity type

The analytic concept *communicative activity type* (Linell, 2009a, p. 203f.) provides a link between micro- and macro-levels: between focusing on the specific in a dialogue exchange and focusing on the communication as a type of social situation. The interaction in a specific situation in certain ways reflects other similar situations. What is seen as belonging to a particular communicative activity type may vary across cultures and times; examples are doctor-patient meetings, job interviews and classroom lessons. The characters of situations of particular communicative activity types are not all the same but are modifications that it is possible to analyse. The communicative activity type analysis (CAT) can be performed on various empirical dimensions, Table 1.

Table 1 illustrates a selection of the many empirical dimensions that together make up the character of a communicative activity type. In order to break down the constitution of a science lesson into components, the conceptual and empirical dimensions of the communicative activity type analysis are helpful. The meanings of words that are central to the topic being taught are defined in the specific situation, topics are given a certain amount of time in the communication, and the teacher's and students' roles are manifested (Framing dimensions, 1st row). The curriculum represents one core communicative project, and the phase structure, turn-organisation and feedback patterns coordinate the teacher and students' communication in the classroom (Internal interactional organisations and accomplishments, 2nd row). Science classroom practices are related to practices in the scientific disciplines as well as in the education system and to teaching traditions in other school subjects (Sociocultural ecology, 3rd row). For the students, the science lesson also implies a get-together with peers and has similarities with other get-togethers, before and after the science lesson (Sociocultural ecology, 3rd row).

Table 1. Communicative Activity Type (CAT) analysis, adapted from (Linell, 2009a, pp. 203-204)

Family of concepts	**Empirical dimensions for CAT analysis, examples**
Framing dimensions (demarcating the specific CAT)	Situation definitions: prototypical purposes and tasks activity roles scenes times medium role of language (central vs. subsidiary) specific activity language
Internal interactional organizations and accomplishments (in the specific CAT)	phase structure core communicative projects agenda topics turn organisation and feedback patterns topical progression methods (question designs) dominance patterns positionings (in)formality role of artifacts
Sociocultural ecology (of specific CATs in relation to their adjacent CATs and organizations)	sociocultural history relations to societal organizations larger activity systems neighbouring activity types positions in chains of communication situations hybridities discrepancies in participants' understandings

For a study of science lessons as a communicative activity type, Table 1 gives some ideas of what empirical dimensions that might afford further investigations. There are examples of previous studies that focus on feedback patterns (Aguiar et al., 2010; Mortimer & Scott, 2003; Scott et al., 2006) and activity roles (Ford, 2008; Ford & Forman, 2006; Ford & Wargo, 2012). Research can contribute to the understanding of many more of the empirical dimensions of science lessons, for instance: time-space relationship in students' meaning-making, the role of temporality and phase structure in science teaching practices, how science teachers make use of language – for example to make conceptual distinctions – and how teachers bring about topical progression in the teaching. These are ways to conceptualise some of the components that make up the science lesson as a particular type of communicative activity.

A foundation for the methodological approaches

In this last section of this chapter on theory, the methodological approaches developed in this project are described. Three approaches are developed, which are of different characters but lie within the same dialogical framework. As a consequence, the methodological approaches give rise to three distinctive but still conceptually related studies in this thesis.

Studying content and interaction

Dialogical theories provide a number of possible analytical entry points, but how to address content in the analysis is still a methodological challenge. As described above, the view of language as social and contextual is fundamental for dialogical theories of communication. This makes dialogical theories potentially problematic for research about education and learning, in that it might lead to content being downplayed (Ongstad, 2004). In the current project, the three different methodological approaches are developed for the analysis of classroom communication. In the three studies included here, the empirical material is tackled differently in each case: sometimes the analysis stays closer to the treatment of content in classroom communication, sometimes the analysis foregrounds the interaction. By attending to the three dialogical principles – act-activity interdependence, sequentiality, joint construction – and by fitting them to the empirical dimensions of the CAT analysis, the various findings from the project are contained within the framework of dialogism. The analysis is directed towards relations between the local level of particular episodes of interaction and recurring patterns of interaction in the classroom. It is primarily a study of conditions for learning and not of learning outcomes.

Three dialogical principles and three approaches

The principle of joint construction

The first dialogical principle, joint construction, focuses on negotiations of meanings. Joint construction, or co-authorship, describes the construction of meaning and common topics in conversation (Linell, 1995). This means that for the building of a topic a single contribution is not enough; rather a series of contributions are necessary. A sustained communication then indicates that

speaker and listener share some background knowledge regarding how things are to be understood (Hanks, 1996). Speakers' shared understandings are derived "…from their ability to work out meaning in contexts" (Hanks, 1996, p. 149). This means that speakers create the conversational context including, for example, agreements on the meaning of words. In such a context, silence may be as meaningful as speech.

In the first methodological approach in this project, this principle directs the attention to the communication as a whole and the central concepts that the participants deal with in the classroom. It is of interest to investigate how common topics are constructed and meaning is negotiated, including how a teacher makes distinctions in order to provide the subject-specific terminology and word meanings. When instances of this are identified, these become the basis for a detailed investigation of how word meaning is negotiated in the classroom (Paper 1).

The principle of act-activity interdependence

The second principle, act-activity interdependence, concerns how communicative acts and activities are mutually defined. This principle states that individual utterances are embedded in the activities of which they are part. Hence, a single action or 'interact' in a dialogue is understood in relation to the whole (Linell, 1995, 2009a). An utterance or sequence of dialogue is part of an activity that might represent a more general type of activity. Linell (1995) compares the communicative activity type with a genre: "Communicative genres are thus originally interactionally developed, then historically sedimented, often institutionally congealed, and finally interactionally reconstructed in situ" (Linell, 1995, p. 143). The genre involves certain configurations of social roles, participant frameworks, possible topics in talk, and turn-taking systems often routinised in an institutional setting with professionals. This points to the part-whole relationship in term of patterns as well as the dynamics of communication.

The principle of act-activity interdependence directs attention to the organisation of the classroom. One of the central issues is understanding individual actions made by a teacher or students in relation to the multiple communicative projects with different purposes that are going on simultaneously in a classroom. In order to do this, a first step is to understand the teaching and learning activities that are going on and map individual actions in relation to the organised activities. The activities provide different

possibilities for teacher and students to act, and represent important conditions for teaching and learning. Specific research questions are formulated in order to investigate the interplay between the teacher and students in the organisation of classroom activities (Paper 2).

The principle of sequentiality

The third principle, sequentiality, signifies the organisation of discourse and accounts for the position of an utterance in a conversation. What happens in a conversation is described as follows: "We can think of the building of *discourse episodes* /…/and the construction of a coherent text and associated context space as starting from a fragment and building around and beyond this an *island of temporarily shared understanding*" (Linell, 1995, p. 69). When a single utterance is taken out of its context and analysed it is recontextualised in terms of a citation and an analytical comment (Linell, 1995). The principle of sequentiality states that in order to understand the meaning of a single utterance, it is important to establish the position of the utterance in the dialogue. This might be done by determining the responsive and projective properties of utterances: what is the utterance a response to and in what ways does the utterance project a specific response? Focusing on sequentiality means focusing on how utterances are contextualised.

This principle directs attention to classroom interaction in a sequence of lessons and how teacher and students fit the lessons together. In this third approach, a systematic investigation is developed of how links between lessons are constructed in the classroom communication (Paper 3).

5 Method

This chapter describes the methods used for empirical design and analysis. The first section discusses the case-study approach and methods for the generation of data. The second section, called "Analysis and reporting", describes the analytical procedures used within the project.

Empirical design

Single case studies

The project can be described as a case study, where the dialogical framework is applied to the video recordings of a series of lectures from one classroom. As previously described, the three dialogical principles work to constrain the analysis of the classroom interaction and direct the focus towards specific issues in the communication. While each study emphasises one of the principles, all three principles are equally important in the analysis.

A real-life case representing an abstraction

According to Yin (2009), a case study may be a particularly feasible design when the boundaries between a phenomenon and the real world context are not yet fully defined. Silverman (2010) describes how case studies identify these boundaries, define the unit of analysis, delimit a research problem that focuses on some features of the case, and still preserve the "integrity of the case" (Silverman, 2010, p. 138). For Flyvbjerg (2001, 2006), the context-dependent knowledge that is produced by the case study is closely associated with the advancement of human learning and the case study is well suited to re-examinations of things that are assumed to be well known. Generalisations from thorough case studies are often possible by "the force of example" (Flyvbjerg, 2006, p. 228). Following this reasoning, a case study is not only an appropriate method but is necessary in order to investigate and identify observations in a complex situation (Merriam, 2009). To be convincing, such investigations rely on multiple sources of evidence that need to converge. From the above descriptions of case studies, projects like the present one

have the potential to provide insights into a contemporary science classroom, if a thorough study of a single classroom practice is carried out.

The single case study was considered suitable for the purpose of the project, as was a study based on naturally occurring data, derived from existing teaching situations and not dependent on intervention (Silverman, 2010). It was assumed that there were things to learn and understand about the activities in science classrooms more generally that an in-depth study of one single classroom could potentially give some insight into. The decision was taken to make a detailed investigation of one science classroom over a sequence of lessons. In science teaching practices, sequences of lessons are fitted together to make up curricular units, and this classification guided the selection of a sample.

The generation of data

The project: Naturvetenskaplig bildning i klassrumspraktik[5] was initiated in 2010 as a collaboration between departments at the Faculty of Education at the University of Gothenburg. The purpose was to generate a body of video material focused on science classrooms and science lessons, for investigating enacted science literacy. The project involved a team of members consisting of researchers, as well as technicians from the LinCS video lab[6] at the University of Gothenburg. The team prepared an application to the regional board and established contact with schools and teachers, as well as preparing the practical and technical arrangements in the actual classrooms and carrying out the recordings. The project included a doctoral candidate position, which was announced in 2011 and which resulted in the work conducted in this thesis.

[5] Translated: Science literacy in classrooms

[6] The Linnaeus Centre for Research on Learning, Interaction and Mediated Communication in Contemporary Society (LinCS) http://www.lincs.gu.se/research_organisation/lincs_lab/

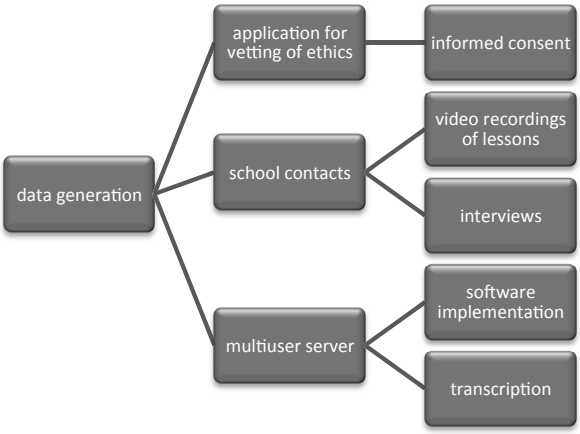

Figure 1. The data generation process

An outline of the process of data generation is shown in Figure 1. The data generation involved implementation of a project design, contacting schools, making video recordings of lessons, conducting interviews with participating teachers and students, setting up a multi-user server, and making transcriptions of recorded materials. An application to the regional board to vet the ethics of the research was prepared before the schools were contacted.

Setting and participants

The project team contacted a network of schools and asked for teachers to volunteer. Members of the team had an interest in researching the teaching of biological evolution, and so this was asked for in the query. One teacher and the students in a group in grade 9 agreed to participate. For the purposes of the research, they agreed that all lessons during one curricular unit about evolution would be recorded on video. The school was situated in a smaller municipality within commuting distance of a larger town. The school participated in a 'one-to-one' project, which means that every student had their own laptop with internet access. A total of 11 lessons about biological evolution were recorded. The project did not interfere with the planning of teaching and carrying out of classroom activities. Instead the teacher was instructed to teach the particular topic in the way that this was usually done by this teacher.

Video recordings and technical design

The recording of the teaching used a technical research design developed at the International Centre for Classroom Research (ICCR) in Melbourne, Australia[7] (see Clarke, Mitchell, & Bowman, 2009). This involved setting up four cameras with connected microphones in the classroom (Figure 2). The sound and picture of the four cameras were then synchronised in real time.

The technical equipment was put in place before every occasion and the cameras started shooting about five minutes before the scheduled start of the lesson. During the lessons three of the cameras were in fixed positions; one of these captured an overview of the classroom (Camera: Class) and two captured students in two groups (Cameras: SG1 and SG2). The fourth camera followed the teacher, who wore a wireless microphone (Camera: Teacher). This camera was also used to capture the notes made on the white board. After each lesson the team organised interviews with the teacher and two students, one from each of two student groups, in a separate room.

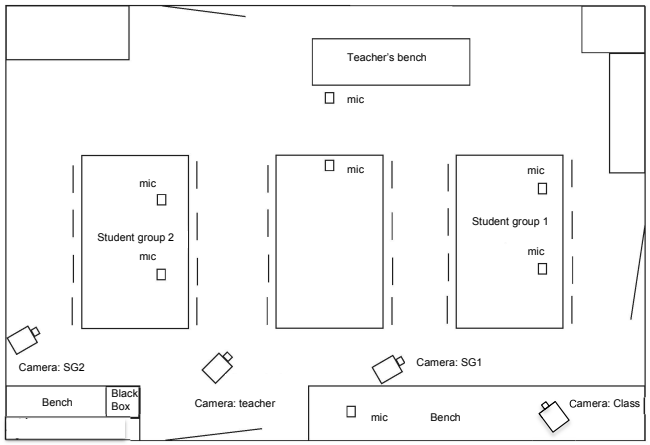

Figure 2. Technical setup in the classroom

The analysed set of video-data consisted of 38 hours of video in total. A verbatim transcription of talk and interaction in the entire teaching unit was conducted based on recordings from the teacher camera (570 minutes). At a later stage, parts of the footage of the student groups were transcribed (200

[7] http://www.iccr.edu.au/

minutes) and during the analytical process more detailed transcriptions were made. The transcribed parts of the student footage were focused on occasions when the students were supposed to work together in their groups, for instance with specific tasks.

Using USB flash drives, the project collected notes that all students made on laptops as well as their written assignments, and a few weeks later the final tests were collected from a selection of students. The textbook and handouts that were used were also collected. The collected materials were stored in a database on a separate server. When the database had been prepared, transcriptions of talk and interaction were carried out.

Analysis and reporting

The analytical procedures conducted in the current project involved watching the videos, making selections, building collections, a detailed transcription of episodes, and making analytical descriptions. Figure 3 describes the analysis and reporting as part of the research process.

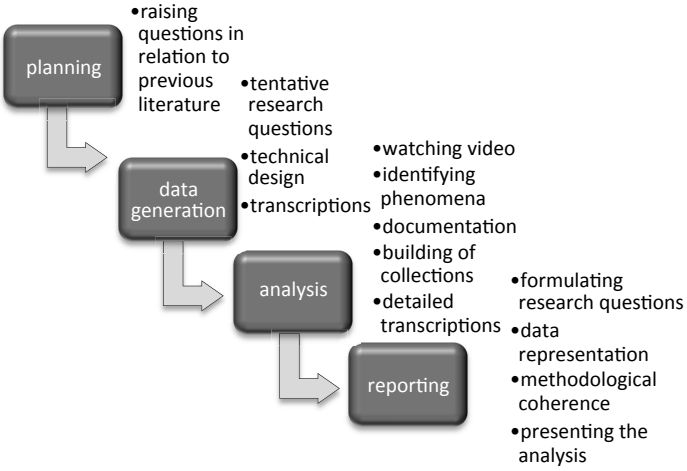

Figure 3. The research process

The empirical material in a school context

The material documented eleven lessons over four weeks. Seven out of the eleven lessons were in whole-class and four were repeated half-class lessons. Lessons were fifty minutes long and the teacher most often started with attendance and general questions before beginning to teach the topic.

Activities in whole-class teaching format dominated the lessons. However, in 10 of 11 lessons some form of small-group activity was carried out. The students were sitting in groups around tables. The classroom was equipped with a whiteboard, sinks and water taps, and a fume cupboard.

The teaching covered the topic biological evolution. During the first lesson, the students were asked about their associations for the words genetics and evolution in an activity similar to a 'brainstorm'. The evolution of the long neck of giraffes was problematised in a couple of lessons. One lesson presented three historical explanations for the evolution of life on earth. One lesson presented the historical perspective on the first living cell and the evolution of different species. A couple of lessons were organised as a practical activity including the description of dry broad beans. One lesson presented cell-structure, reproduction and some basic genetics. A few weeks after the sequence of lessons, the students were given a summative test on the unit. The eleven lessons are described in detail in the papers included in this thesis.

The period reflected in this project represented a period of school reforms. At the time of the study, February-Mars 2011, Lpo 94 (National Agency for Education, 2006) was the governing curricula, implemented in 1994 and replaced in August 2011 by Lgr 11 (National Agency for Education, 2011). This means that during the spring of 2011, when the data was collected, Lpo 94 was a document that was well known to the teacher. The goals and pedagogical ideas expressed in Lpo 94 can therefore be assumed to have influenced the everyday teaching practice to the same extent as in other classrooms by that time.

The participating teacher, who was formally trained to teach the subject, had been teaching for about ten years altogether and had been teaching this particular group for about two and a half years. The 23 participating students, 13 girls and 10 boys, were in their final term in lower secondary school. The collected materials were rich and promising for the purposes of further inquiry in the present project. The data provided detailed information about the activities in a science classroom over several lessons and the variable discourse patterns displayed in the communication were appraised for their potential to be analysed.

The analytical procedure

In operationalising the purpose, there were different options both with regard to empirical design and with regard to data selection for analysis and analytical procedures. This was a gradual process in which the documentation and preliminary research questions were tried out together with different representations of data. The work included the watching of video material in order to select particular video segments for further analysis, the identification of study objects, and the making of collections.

Getting an overview

Analysing the video was a process of looking into a massive and complex system of interaction. Lemke (1998) describes in the following way the steps taken after having conducted video recordings of the classroom setting:

> Having done all this you will be in possession of a vast archive of data, which you will never be able to analyse exhaustively. You sift through it in search of salient patterns, often guided by the differences between your perceptions and those of the people you visited. When you identify a candidate pattern, you look for other instances elsewhere in the data, and very often you then notice still other patterns. These are patterns within language data or visual data or semiotic data of other kinds and between them. (Lemke, 1998, p. 253)

This is a description that also applies to my initial experiences when encountering the video material and starting the analysis in this project. The difference was that the data generation project team collected the material, and therefore the approach, analysis and investigation were based primarily on the recorded video material.

Green et al. (2007) include the students as ethnographers in their own classroom in the project description of the group of ethnographers. This means that, in their case, the project and the development of understandings of the classroom practice was a collaborative work. In contrast, this is an individual project in which the feedback from supervisors played a significant role for the understandings developed at different stages of the process.

There were three things that were noticed early on and that remained interesting throughout the analytical process. The main reason why these three observations, in contrast to many others, resisted being discarded was that they were strongly represented in the material and that this was documented throughout the process. The first thing that was noticed was the

talk about explanations. Scientific explanations are central in the science subjects and the extensive talk about various explanations that went on was potentially interesting. The second thing was the work in small-groups. In this classroom, the students were repeatedly given tasks to solve or problems to talk about in groups, and differences between groups could be observed by watching the video from the student group cameras. The third thing that was noticed was the frequent comments that were made in the classroom. These comments were made in connection with the specific topic being taught and sometimes moved the conversation in other directions. A more detailed analysis revealed that some of the comments involved the teacher and students drawing connections between lessons and different conversations held in the classroom.

Formulating research questions

The early observations illuminated certain patterns in the classroom communication that transcended the individual lesson, and the material provided a certain amount of empirical data for further investigation. Thus, three different studies were designed and performed, each representing a particular exploration of the material articulated through sets of more precise research questions. Each study investigated an aspect of the classroom by using corresponding theoretical/analytical concepts and by attending to the principles of act-activity interdependence, sequentiality and joint construction. The theory was helpful for maintaining distinctions, for example in the building of a collection, in articulating a question, and in describing and interpreting a phenomenon. Conceptual distinctions, classroom organisations, and connections between the lessons were in this way gradually conceptualised. The analysis developed along three lines (Table 2).

Table 2. The development of three studies

	Early observation	Study object	Paper Research question	Theoretical analytical concepts
Conceptual distinctions	talk about explanations	How "explanation" is used in science education	Paper 1: 1) What consequences do the many meanings of the words *explanation* and *explain* have for science teaching practices?	Meaning potential
Classroom organisations	work in small groups	How topic progression and teaching and learning activities are coordinated	Paper 2: 2) What opportunities for student participation are provided? 3) How is the interplay between teacher and students regulated?	Temporality Participation IRF pattern
Connections between lessons	comments and references transcending the individual lesson	How a set of lessons in biology are connected	Paper 3: 4) What characterises the link-making process in classroom communication in a unit about biological evolution? 5) How are link-making strategies used in relation to the development of interrelated topics in a curricular unit?	Recontextualisation Intercontextuality

The question in one of the studies was: What are the consequences of the many meanings of the word explanation for science teaching and learning practices? The question articulated that this investigation focused on instances of the word explanation and the dynamics inferred by this word in the communicative context. In the second study the questions were: What opportunities for student participation are provided? and How is the interplay between teacher and students regulated? The two questions were used for an investigation of patterns of student participation. Finally, in the third study one of the research questions was: What characterises the link-making process in classroom communication in a unit about biological evolution? This question emphasised how teacher and students made connections to previous and future teaching.

Reducing the complexity

Derry, Pea, Barron et al. (2010) claim that to break down complex video events is a process influenced both by what actually occurs and by the researcher's perception and knowledge about the practice. In this analysis my

experiences of working as a science teacher contributed to an understanding of some of the teacher's and students' actions. The analysis also benefitted from sharing and analysing material with experienced researchers in data-sessions, among them members of the project team. In this form of workshop, described by Heath, Hindmarsh, and Luff (2010), a group of researchers together watch and talk about short fragments of video. These kinds of discussions and repeated viewings of video material supported the emerging analysis.

Green, Skukauskaite, Dixon et al. (2007) write about their analysis of video recordings of science activities in a class from the perspective of interactional ethnography: "From this perspective what is captured on video records are the actors, their words and actions within a developing cultural context, as well as visual texts related to the physical spaces, objects, and graphic artifacts of the classroom" (Green et al., 2007, p. 118). In their examination, they focus on the members' construction of local knowledge and patterns in ways of communicating, knowing, being and doing through interaction. The analysis is performed from two angles, the collective (analysing discourse and social actions) and the individual (analysing how individuals within the group use material resources or take up what is constructed on the collective level). There are many similarities between the approach by Green et al. and the video-analytic approach in the present project: the multi-scale approach, the view of the classroom as a culture, how the researcher reads the same signals as the actors. This is similar to the way the video recordings in this project are watched and participants' actions are analysed: what they mean, what actions are expected and appropriate, and how these are connected to actions in previous or future events. However, while Green et al. uncover layers of constructions that co-occur in the classroom in order to look at local constructions of identities and knowledge access, the present project lingers over the details of the practices. In this project the data representation element is emphasised by selecting critical episodes, analysing the details, and developing representations of these complex patterns.

Documenting

Documentation during the analytic process was carried out using tables, graphical representations, individual frames from the video material but mostly as analytical descriptions. The documentation process involved both identification and representation of phenomena (Figures 4 and 5). During the

process the representations were continuous, which gradually increased their precision. The changing classroom activities, the patterns of student participation, the tasks worked with as well as the topics and central concepts were documented. This documentation grew and became a method of getting to know the details in the whole of the empirical material.

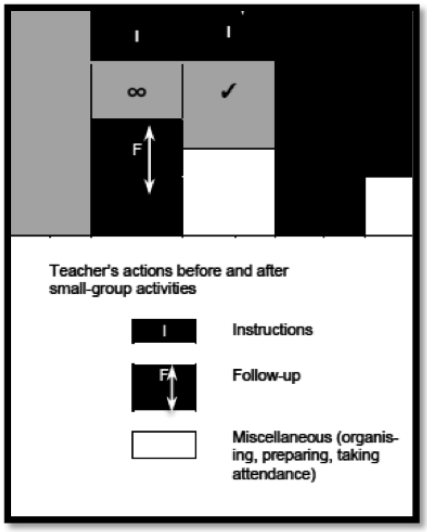

Figure 4. Detail of data representation (figure from Paper 2)

Reveles, Cordova, and Kelly (2004) use a timeline to describe the classroom science activities over the academic year and an event map for a detailed representation of steps in the performance of a specific classroom activity and lesson. In their description of the context for a particular episode, the two representations work as complements. Derry et al. (2010) call the selected events time-analogs for objects, which it is possible to analyse on the level of even smaller events or as part of larger macro-scale events. Lemke (2000) illustrates an educational timescale ranging between, at the micro-scale, the signals in neurons in the brain of an individual student in a classroom, and at the macro-scale, the development of societal systems for education. In this range of possible scales, video technologies suit an analysis of a narrower range.

In this project, the eleven lessons represented the largest event and parts of lessons represented the shorter events, such as a particular activity, minutes of a conversation, or parts of seconds (for example a particular gesture, a student

taking a quick look at the white board, the teacher turning around and leaving a group of students). The analysis alternately focused on longer and shorter timescales. In ordering the selected events and keeping the orientation in the recorded material, the transcribed material from the teacher camera provided useful time-codes.

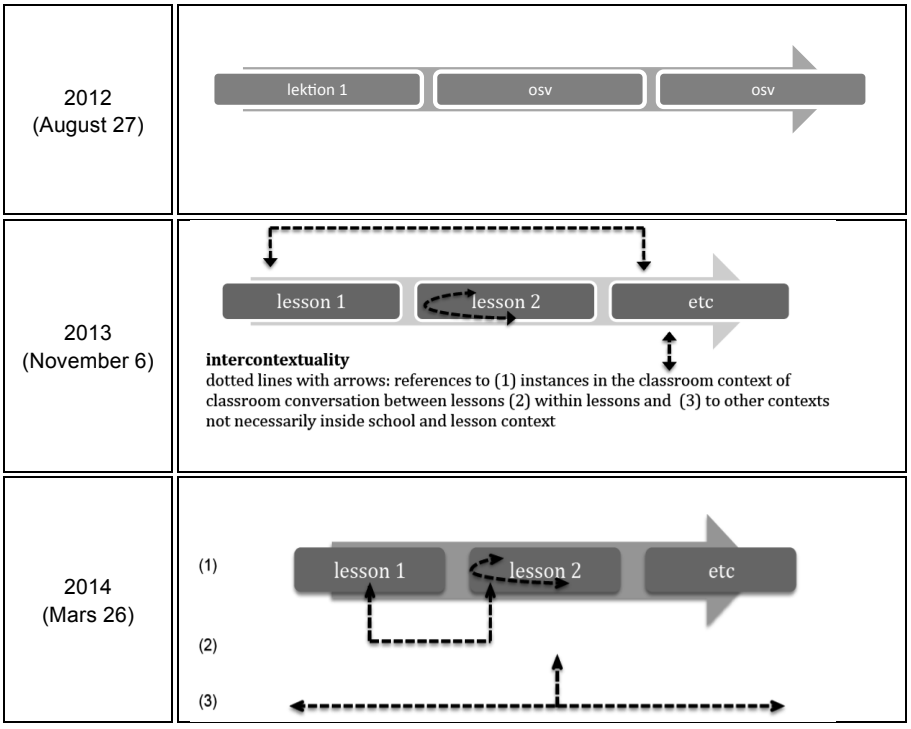

Figure 5. Development of a model used in Paper 3

Analysing collections, contrasting cases and trajectories

The research questions and theoretical perspective guided multiple cycles of analyses in which the selection of individual episodes was a final part. Firstly, events that recurred in the communication and that were significant for the continuation of teaching and learning activities over several lessons were focused on. Secondly, a strategic decision was made to address aspects of the classroom communication by using specified research questions and to construct a separate collection of data for the investigation of each question. Thirdly, the separate collections were investigated and analysed with regard to different patterns found in the communication, and individual episodes were

analysed with regard to how this range of patterns could be represented. This way of operationalising the purpose contributed to a stepwise process in which the large body of video material was analysed.

In each case the systematic mapping of individual occurrences and patterns in the classroom included the building of separate collections of data. The making of a collection was preceded by decisions on how to identify and collect all relevant instances from the body of video material. For instance, in order to build a collection of the teacher's use of the word *explanation*, the decision was made to include all those words that were supposed to be informative, which included words like *explain* and *the explanations*. The documentation of almost one hundred instances was a promising collection of how this word was used in the particular context.

In order to build a collection of activities, decisions were made on how to distinguish the start and end of different activities. In each phase it was orientations towards ways of participating and controlling the right to speak that were considered. The documentation of a total of thirteen small-group activities performed in ten out of the eleven lessons resulted in a collection based on the many transitions that followed from this activity pattern. Episodes showing contrasting cases of student participation and teacher control were selected and analysed.

After these decisions about how to build the collection came the practical work of carrying it out. This involved a process of going through the material and documenting time-codes, interactions and themes developed in the talk for all the selected instances so that they could be easily retrieved. In this way the analysis proceeded little by little, carried out on different collections from the same data source, and in this process the selection of episodes was a significant element.

Selecting and representing episodes

Heath et al. (2010) emphasise the importance of analysing individual instances for the role of evidence in video-analysis, while Derry et al. (2010) describe 'story-telling' or selecting episodes in order to support a narrative. One approach could have been to focus only on individual episodes in the classroom. Another approach could have been coding and counting different actions in the classroom, for example the use of particular terms, as in the approach used by Clarke et al. (2009). Episodes could also have been chosen for the purposes of illustrating a theoretical argument. In that case, the

selection of episodes would be motivated by the aim of understanding the theory rather than understanding the practice. Selection of episodes could also be based on contrasting cases, trajectories or collections, each type grounded in its own particular logic. In order to respond to the purpose and research questions, the analysis in the present project uses these types of selection processes but in specific combinations.

When shorter episodes of interaction were selected for analysis, the transcripts were iteratively revised and gradually became key data used for coding, interpretations and analytical representations. Here, the revised transcriptions were made on an intermediate level of detail, using a selection of transcript notations to indicate, for example, emphasis, overlapping speech, pauses, and gestures. The iterative transcriptions were fruitful in finding interesting and critical episodes, and this is supported by the literature on video analysis (Derry et al., 2010; Heath et al., 2010). In the reporting, great effort was invested in making accurate translations of the speech to be included in the excerpts. In several cases, the original transcriptions were made available together with the translations, as appendices to the manuscript.

Discarding and abandoning what did not turn out to be convincing descriptions of activities in the particular classroom were important selection procedures. One example of a preliminary approach that was abandoned was focusing separately on the teacher's actions, the students' actions, and the interplay between teacher and students. By attempting this preliminary approach and trying out questions, building collections and analysing the details of communication in episodes, the intertwinement of teacher's and students' actions and occurrences in the classroom became obvious. The analysis showed that this approach was not compatible with either the character of the empirical material or with the purpose. To view the teacher's actions separately from the students' actions was simply not justifiable; it counteracted the purpose as well as the character of the specific empirical material. Hence, the approach was abandoned and instead, the further analysis emphasised the intertwinement of teacher's and students' actions in the communication. This is only one example among a number of questions, analytical approaches and selected episodes that were abandoned.

The analysis manifested a combination of interests in larger and smaller perspectives on the science classroom, in social interaction and science content. The interest in the school subject as a whole and in learning about the role of content in classroom interaction was combined in the analysis with

an interest in temporality and working with lessons as well as details of interaction. The operationalisation of the purpose developed into three studies and an analysis in the form of three research article manuscripts.

Ethics, validity and generalizability

Ethical considerations

The work included in this thesis complies with the code of conduct for social science research (Swedish Research Council, 2014)[8] [9]. This means that ethical considerations were important not only during data generation but during all stages of research, including the analysis and reporting. First of all being invited to share what was going on in a classroom with the teacher and students in the detail that four cameras and microphones allowed, was an opportunity. As a researcher, I regarded it as my responsibility to do justice to the richness of the material and to make the efforts needed for an original contribution.

An application for review was prepared and sent to the regional board for vetting the ethics of research involving humans. The application included a description of the aims of the project and the technological design for the capturing of classroom data, and a presentation of the researchers involved. The response from the regional board was that the design of the project did not demand vetting of ethics. However, the regional board offered some advice that guided the provision of information and the procedure with regard to obtaining informed consent from the participating teachers and students.

The teacher and the students gave their informed consent for participation in the project (see Appendix for details of this document). Additional information was provided in the form of a newsletter for the parents and legal guardians of students. The participants agreed to the video recording of lessons as well as to being interviewed by the research team.

All work within the project was carried out following the legislation in the Personal Data Act (SFS 1998:204). The data material was treated confidentially: documents were kept in locked cabinets and video recordings were kept on a separate server with password-protected accounts for the team members. Multi-user software[10] and the separate server enabled flexibility with

[8] http://www.codex.vr.se/forskninghumsam.shtml
[9] http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SHS/pdf/Soc_Sci_Code.pdf
[10] Transana 2.51 MU

regard to geographical locations. The project team were able to work simultaneously – individually and together – with video recordings and transcriptions. This reduced the need for local data solutions in this project to a minimum. For temporary off-line use, material was stored on a password-protected external hard drive.

To ensure the anonymity of the participants, the names of the teacher and students as well as of the local school and the municipality were replaced or removed during the second and more detailed transcription of episodes and in the reporting. It was also part of the ethical considerations to make accurate representations and be true to the material in the formulation of questions as well as in the reporting of research. The excerpts from the material were cut down so that only relevant interaction was represented, in order to provide precise illustrations of the findings in relation to each specified research question.

Validity

Silverman (2010) compares validity to truth. Following this, evaluating the validity of a study means assessing whether a study provides a truthful picture of reality. In order to strive for validity during the research process, some of the strategies that Silverman describes have been a part of the present project. One strategy is that of triangulation. Silverman makes a distinction between *method triangulation* and *data triangulation*. Method triangulation means combining different ways of looking at a situation, while data triangulation means combining findings from different data sets. There are similarities between these accounts of triangulation and the practical execution of the three studies included in this project. For instance, Silverman underlines the importance of not trying to provide the 'full picture' (2010, p. 135) but beginning from the theoretical perspective and choosing the combination of methods in light of the theoretical perspective. In the project, theory was an important point of departure and the approach with multiple methods was used, not just for aggregating data but also in order to apply methods that could possibly contribute findings relevant to the particular theoretical perspective. While it is the case that the project is developed on one single data source, the three separate approaches and constructed collections provided different data records for the more detailed investigations.

Two additional strategies that Silverman mentions are the *constant comparative method* and *comprehensive data treatment*. The constant comparative

method means that all data fragments arising in a single case are to be inspected. For large data sets difficulties may arise because of limited resources, for example, for making full transcriptions or for assembling data in analysable forms. For this project, the multi-user server and software, as well as the first level of transcription, were essential. This provided a structured material, enabled flexibility and facilitated the alternating focus on short and longer fragments in different parts of the material. Comprehensive data treatment means that all cases are incorporated into the analysis. For the researcher, this is a demand that means that even if a single episode is what is represented in the written report, this episode is simply representative of all other cases of that kind. That does not mean that it is not unique, but that the generalisations that the analysis provides are applicable to all relevant cases. The results from a comprehensive data treatment strategy are detailed accounts of specific phenomena that, according to Silverman, can be as valid as a statistical correlation. Here, the strategy has been to provide the necessary details for understanding the investigated phenomena but never to provide causal accounts of the different events analysed. The above-described methods are used strategically in order to strengthen the validity of the project findings.

In assessing the current project, one important aspect is whether the observations are based on reliable data. This means, for example, that if the participants' behaviour was very influenced by the research situation, then the observations of the recorded material and what is conceptualised in the analysis might be misinterpretations. The presence of researchers and technical equipment naturally had effects on the teacher and students. In the material this could be seen when students looked straight into the camera or when the teacher posed a question to the technician about the position of a microphone. It can be assumed that the teacher and students wanted to contribute and made great efforts during these lessons. However, such examples of awareness of the research situation did not influence the investigation and the answering of the specific questions posed in this project. Other things were more important. For example, the classroom interaction indicated a habitual interplay between the teacher and students. There were no signs from the students that the teacher's actions were unfamiliar to the students or that these lessons proceeded in any unusual way. On the contrary, the students' reactions to the teacher's actions and instructions, and the

activities introduced, indicated the presence of a routine and that the teaching proceeded in ways that were usual for the group and classroom.

Generalizability

A critical question is whether a case study provides the basis for any generalisations. For the current project, the single-case approach provided possibilities for investigating one classroom practice in some detail. At the same time, a contrasting case comparing two classrooms might have provided other possibilities, such as illuminating differences between the classrooms regarding the three aspects: conceptual distinctions, classroom organisations, and connections between lessons. At the level of individual actions in episodes, the occurrences described in the analysis are unique and cannot be generalised. At the same time the patterns that are also described are more general and as such can be assumed not to be unique to this particular classroom.

When generalisability of qualitative research is discussed, specifically in relation to case studies, the statement that *the general lies in the particular* recurs (Flyvbjerg, 2001; Merriam, 2009; Silverman, 2010). Silverman emphasises that the single case study does not provide a truth but is an attempt to raise questions while looking closely into one possibility for a practice and the use of language within the practice. For Merriam (2009) it is the researcher's responsibility to provide sufficient description and contextualise the study in order to make it possible for the reader to determine whether the findings are applicable to their situations and therefore transferrable. Flyvbjerg (2006) claims that it is a common misunderstanding that generalisation from a case study is not possible. One generalisation that he suggests is 'falsification', a term used by Popper. This implies constructing scientific propositions that may be falsified by only one observation that does not fit the proposition. Thus, a case study can provide the single piece of evidence needed in order to falsify a previous proposition. This put demands on the researcher to be as accurate and precise as possible and to perform a cautious treatment of findings to provide the necessary details of the case while remaining aware of the limitations of the study. When Flyvbjerg writes about 'the power of example', the case study research is compared to human learning. First, Flyvbjerg claims, the detailed view that a case study provides is important for a meaningful understanding of human behaviour. Second, Flyvbjerg argues, the case study is a method that forces the researcher to keep close to the

empirical analysis and therefore a way to avoid the ritual 'blind alleys' and to effectively learn the skills of researching. These two descriptions apply to the work in this project. The driving force in the process was to understand and to try to learn from what went on in the investigated classroom. It was the case that was interesting and not how to develop a case study design. Trying to develop analytic skills while working closely with the empirical material was both a challenging and a rewarding process.

6 Research results

In this chapter the studies are presented and the results of the project are summarised. Each paper employs a particular approach with more specific research questions in order to understand the three aspects that are the focus of this project: conceptual distinctions, classroom organisations, and connections between lessons. In this summary each of the three papers is first presented briefly, then the project as a whole is outlined and finally the results of the three studies are summarised.

Three studies

Paper 1

The many roles of "explanation" in science education: a case study

The paper takes its point of departure in the literature and a conceptual confusion regarding the uses of *explanation* and *argumentation*. The question under investigation is in what way a teaching practice is affected by different uses of the word *explanation*. Three meanings of the word are presented as relevant in the context of science education: *an everyday meaning, a pedagogical-professional meaning* and *a scientific meaning*. A case study of ninety-eight instances finds that the teacher uses words such as "*explain*" for the purposes of encouraging students to work and to guide students in their learning of how to evaluate and justify different kinds of explanations. In the carrying out of different teaching and learning activities, the teacher creates three conversational structures that provide opportunities for dealing with explanations. The three conversational structures are: asking for acts of explanation, providing opportunities to talk about what explanations are in this context, and providing opportunities to talk about explanations constructed by students. The description of three meanings of the word "*explanation*" and their coexistence in science classrooms is of significance for the understanding of the communicative challenges involved in science teaching and science learning.

Paper 2

The temporality of participation in school science: Coordination of teacher control and the pace of students' participation

In this paper an in-depth study of classroom activities and student participation is performed, focusing on the interplay and the regulating mechanisms between teacher and students in the different activities carried out. The analysis shows the pace of student participation as a practical concern for the teacher and the regulating roles of time and topic progression. In the coordination, query-constructions and small-group activities are used in order to frame discussions in relation to biological evolution. These queries allow the teacher to check students' understanding in a series of tasks with increasing levels of complexity. In the follow-up, the teacher explains the tasks and embeds students' contributions into the whole of the teaching. The description of an activity pattern, and students knowing and not-knowing positions when participating, has implications for how different paces of participation ought to be coordinated and taken into account in science-teaching practices in order to provide students with equal opportunities.

Paper 3

A topic trajectory about survival: analysing link-making in a sequence of lessons about evolution

The paper investigates connections that are made in the classroom between current, previous and future classroom activities. The teacher's and students' link-making strategies are shown to make connections between activities within the lesson, between activities within the unit, and between the current activity and other teaching and learning activities outside the unit. Link-making serves many purposes: organising, motivating, developing topics, and checking understanding. Typical examples are when students ask questions about what the teacher has written on the white board, when the teacher postpones issues in order to stay with a teaching agenda, or when the teacher addresses discussions from previous lessons about perceived difficulties. A topic trajectory shows how questions are raised in connection with talk about the survival of species. The analysis shows that students potentially share the responsibility with the teacher for advancing the trajectory in line with curricula.

Table 3. Project overview

	Paper 1	**Paper 2**	**Paper 3**
Focus	**Conceptual distinctions**	**Classroom organisations**	**Connections between lessons**
Title	The many roles of ”explanation” in science education: a case study	The temporality of participation in school science: coordination of teacher control and the pace of students' participation	A topic trajectory about survival: analysing link-making in a sequence of lessons about evolution
Purpose	to re-examine the use of words such as *explanation* and *explain* by teachers and students in science-teaching practice and seeks to discover the meaning of these words as they are used in teacher and students' participation in activities	to investigate the interplay between formats for student participation and the strategies used by a teacher to organise and coordinate teaching, specifically in relation to the subject being taught	to study teacher and students' strategies for link-making in a sequence of lessons about biological evolution
Research questions	1) What consequences do the many meanings of the words *explanation* and *explain* have for science teaching practices?	2) What opportunities for student participation are provided? 3) How is the interplay between teacher and students regulated?	4) What characterises the link-making process in classroom communication in a unit about biological evolution? 5) How are link-making strategies used in relation to the development of interrelated topics in a curricular unit?
Study design	Grammatical and dialogical analysis of a collection of instances when the teacher uses words such as “explanation”	Multi-scale analysis of classroom activities, specifically talk and interaction before, during and after small-group activities during eleven lessons	Temporal and content analysis of a collection of explicit references made by the teacher and students to prior and future classroom activities
Findings	- Three conversational structures: 1) asking for acts of explanation, 2) talk about what explanations are in the context, 3) talk about student constructed explanations - Coexisting word meanings	- An activity pattern - The function of small-group activities for coordinating the paces of students' participation - Students' knowing and not-knowing positions	- Teacher and students' link-making strategies: 1) organising, 2) motivating, 3) developing topics, 4) checking understanding - A topic trajectory about the survival of species

Summary of the results

The making of conceptual distinctions

The project investigates how conceptual distinctions regarding the use of the word *explanation* are made in a science classroom. In the investigated classroom, the many discussions about explanations make *explanation* into a central concept. The results are three conversational structures where the teacher and students distinguish between potential meanings of the word explanation. Empirical evidence about coexisting word meanings and a range of illuminating examples are given in Paper 1.

Finding: Three conversational structures

The conversational structures identified here are: asking for acts of explanation, talking about what explanations are in the classroom context, and talking about student-constructed explanations. These three structures are platforms used by the teacher to teach about what an explanation means in the context of the specific topic and classroom, and this is also what she expects the students to learn during the sequence of lessons.

The first conversational structure is when the teacher asks for acts of explanation, as in the question: "Can you explain why?". Examples show how the teacher as part of teacher-student dialogues and practical instructions asks students to explain. This creates situations in which it is appropriate for the teacher to make formative assessments about students' learning and to make decisions concerning the progression in teaching. The word "explain" is shown as a strong driving force in teacher-student dialogues; for example, one student provides a falsification of other plausible explanations, which enables the teacher to deduce an explanation that includes the genetic origins of traits. To apply systematic reasoning, such as causal reasoning, as in this case, represents something that in the science subjects is crucial for constructing knowledge claims, for giving an explanation of a phenomenon or predicting the outcomes of future events.

The second conversational structure is when the teacher and students talk about what explanations are in the context. Essential features of three model explanations are pointed out in the classroom and used for qualitative comparisons. In one short episode, the teacher (de)constructs the biblical story of creation as a valid explanation in the context. In this particular

situation it is the inconsistency between a creationist model and species development that is pointed to. The way this is done with minimal resources shows how conceptual distinctions are dependent not only on conceptual frameworks but also on a common communicative frame of reference, on the use of gestures and on timing. For instance the teacher makes quotation marks in the air, which shows that biological evolution is not a particularly controversial topic in the classroom, at least not one that is openly contested.

The third conversational structure is when the teacher and students talk about student-constructed explanations. The short texts that groups of students have written in the first exercise about the evolution of a physical trait are used as a resource for all students for comparing ways of reasoning with the three model explanations. A dynamic discourse is created that allows for discussions about details of word use and for reflections about students' learning processes. One situation described here shows how students, together with the teacher, make comments on their own processes of learning how to distinguish between two model explanations of evolution – Lamarckism and Darwinism. The episode shows that the students are able to distinguish the two explanations from each other in the talk and the conversational structure – talking about students' constructed explanations – makes this distinction available to the group.

Finding: Co-existing word meanings

Co-existing word-meanings illuminate the communicative challenges that are involved in the task of making conceptual distinctions. Also, this gives insight into what potential word meanings are apt to occur in the context of a science classroom. The examples show how different meanings of the word explanation co-exist. In the presentation of the three model explanations, the biblical story of creation is included and the words *Theories/explanations of evolution* are put on the white board. In this situation, the word explanation is used to denote a theoretical model of evolution based on certain underlying ideas. This meaning coexists with the use of the word explanation in a scientific sense and the use of the word explanation in an everyday sense. In science, an explanation describes causal or conditional relations in sequences of events, and in everyday life an explanation is expected to bring further understanding of purpose. The teacher searches for the proper words and puts the biblical story of creation in quotation marks using a gesture in order to be precise and indicate that this "version" is not valid; the students express

their difficulties with accepting an explanation as such when it does not provide an answer to why evolution occurs.

In a science classroom it is crucial to identify differences and make distinctions between explanations of a phenomenon in order to critically analyse and evaluate knowledge claims. The word explanation is only one example of how different traditions of using language use the same word to convey different meanings. This project shows that in the science classroom these traditions are resources and permeate the communication at all levels down to the level of individual words. The orientation to the topics and topic progression involve the use of resources that have been developed within school science traditions; the informal character of the classroom communication and talk between peers involve resources that have been developed during language use in everyday life; and ways of questioning, reasoning and explaining, and the use of particular concepts and principles involve the use of resources that have been developed in the science disciplines.

The classroom organisation

This project provides a description of organisations in a contemporary science classroom practice by an investigation and detailed documentation of activities in a sequence of lessons. The description in Paper 2 includes activity patterns, the teacher's coordination and forms of student participation. Recurring small-group activities provide opportunities for different paces of student participation and for the teacher to check students' understanding.

Finding: Activity pattern and topic progression

An activity pattern describes the organisation of the eleven investigated lessons. The pattern shows alternating small-group activities and whole-class activities. Small-group activities are preceded by a short instruction from the teacher and follow-up is performed afterwards either in direct connection to the small-group activity or later one of the following lessons. The transitions between phases of activity are coordinated by the teacher. The different teaching and learning activities imply interplay between teacher control and student agency and changing roles for the teacher and students. By taking the front position in the classroom, the teacher takes a particular role that allows the ignoring and postponing of student contributions. By leaving the front

position in the classroom, the teacher takes another role that allows the checking of students understanding. The whole-class and small-group activities provide different opportunities for participating in and contributing to classroom discourse, for listening, reading, discussing, explaining and reflecting. Students participate with questions and comments during whole-class teaching and proceed freely in relation to a specific task during small-group activity. Students check their understanding in the whole-class activities by asking questions and commenting or reporting back – sometimes only symbolically. During the small-group activities the students make themselves accountable for answering and checking whether other students understand.

Before the small-group activity, the teacher poses questions as an introduction to a specific topic and gives practical instructions to the small groups about things such as time frames and expected outcomes. The increasing complexity of questions used by the teacher indicates the topic progression in the unit. Over the eleven lessons the questions become increasingly complex, going from asking for general conclusions, to asking for predictions of phenomena and towards asking for explanations of sequences of events. In this way, these questions, the students' contributions, and the small-group activities are embedded in the teaching as a whole. This shows that topic progression has a regulating function for the proceeding of classroom activity in a curricular unit.

Finding: The functions of small-group activities

The activity pattern with alternating whole-class and small-group activities indicates how different paces of student participation are coordinated in the classroom. A fast pace is associated with students being prepared to answer and complying with ways of reasoning in the science classroom, such as causal reasoning. This is illustrated by the talk among one group of students working with a task. In this example the students take a knowing position in relation to a specific task, which has an influence on the communication and the jointly constructed explanation in this group. This pattern of knowing in science is contrasted with a pattern of participation that displays resistance. The talk among another group illustrates students taking a not-knowing position. In this example, the students repeatedly defend themselves for not knowing and against being responsible for answering the teacher's question. These students say that they lack the relevant resources and the communication is oriented towards one of the concepts being introduced. The two contrasting pictures

and the teacher's actions when approaching the second group of students show the coordinating function of small-group activities. The small-group activities allow the teacher to catch up with the students' difficulties and levels of understanding, to give support to groups of students, and to adjust teaching according to the different paces of students' participation in the classroom.

How lessons are connected

The project shows how a teacher and students in their communication connect eleven individual lessons into a curricular unit about evolution. A system of link-making strategies and a topic trajectory are represented (Paper 3). The topic trajectory identifies moments when questions and objections are raised in relation to the talk about survival and extinction of species.

Finding: Link-making strategies

A system of link-making on different scales shows how teacher and students construct links between the current teaching and learning activity and prior or future activities, within the same lesson, within the unit of eleven lessons, and outside the unit. Both teacher and students construct links to forthcoming activities within the same lesson but it is the teacher that links to future lessons in the unit and outside the unit. The teacher constructs links, for example when something new comes up in the classroom. In order to organise and stay with the original teaching agenda, the teacher postpones issues until a future occasion and refers to a previous topic. The teacher uses link-making to motivate students, for example by confirming that a topic is difficult and assuring students that this will be dealt with in the next lesson. The teacher also uses link-making to develop topics such as new concepts or principles that connect or may explain something previously discussed. Students use link-making in order to check understanding about issues, such as different phenomena brought up in the classroom or the meaning of words written on the white board, or to ask about a particular instruction for the next activity. The students also make links to previous teaching and learning activities in form of comments confirming common learning experiences, like visiting the theatre together.

The study shows the organisation of the unit about evolution, which involves eleven fifty-minute lessons spread over four weeks. This represents a

fragmentation in the temporal arrangement and shapes the science teaching and learning events. Continuity is therefore an important supporting structure for the science teaching and learning. The study shows how the teacher and students create continuity in their communication by making comments and connections between the lessons in the unit. The connections structure the communication and position conversations and individual lessons in relation to other conversations and other lessons.

Finding: Questions about the survival and extinction of species

The study shows a series of four situations in which the teacher and students articulate questions about the survival and extinction of species in relation to the teaching and learning about evolution. This topic trajectory runs from the first lesson in the unit, when one student asks a question that the teacher puts on the white board through talk about some student difficulties during the fourth and fifth lesson, articulated first in an informal talk between the teacher and two students, and then in terms of a student making an objection to an expression used by the teacher in a whole-class situation. The topic trajectory is finalised by a question about resistant bacteria in the final lesson, which is asked by the teacher, and also put on the white board. In the science subjects, it is important to learn how to connect scientific concepts. Putting the concepts together in correct ways means understanding a phenomenon and a thematic area. This project shows that using topic trajectories is a method of tracing and analysing situations where students' questions and difficulties about a specific topic are addressed in the classroom.

7 Discussion

This chapter discusses the results. It starts by recapping the purpose of the project and the results are then discussed in terms of what this analysis of a science classroom practice can reveal about science classrooms more generally. The discussion returns to the literature and some issues that previous chapters brought up, and ends with some conclusions.

Analysing a science classroom

The purpose of the thesis is to identify and describe three aspects of the formation of a science classroom: the making of conceptual distinctions, classroom organisations, and the making of connections between lessons. By identifying, investigating and describing how the word explanation is used, how topic progression and teaching and learning activities are coordinated, and how link-making is used to connect a set of lessons in biology, the project responds to this purpose. Moreover, the project demonstrates the role of temporality and provides an empirical base for discussions about how different thematic patterns are linked to instructional activities and interaction formats in classrooms.

Eleven lessons about biological evolution

The results from this project contribute a detailed analysis of eleven lessons in a sequence about biological evolution. This is a topic that encompasses many challenges for teaching and learning, which literature shows (Kampourakis, 2014; Rector et al., 2013; Rosengren, 2012; Smith, 2010a, 2010b). These challenges involve many concepts, lexical ambiguities, evolutionary processes over vast timescales, explanations on different levels of organisation (genetic, cellular, population, groups of organisms), and theories that at times are conceived of as being controversial.

Reasoning about evolutionary change

The results from this study show a classroom in which biological evolution is taught and learned through reasoning in whole-class and small-groups and a

set of mutually communicative and cognitive activities. The thinking and communication are carried out while teacher and students are talking about evolutionary issues, such as: Why did certain species survive? How can it be determined whether or not a trait is transferred to the offspring? How did the first living cell come about? This project investigates the time-frame within which the students in this classroom are supposed to learn how to reason about such issues. This implies that students are not only supposed to provide correct answers to these questions but learn how to reason in ways appropriate for the subject biology in lower secondary school.

One of the activities that students are supposed to employ is to compare and evaluate three explanations to the evolution of life on earth provided in the classroom: the biblical story of creation, and Lamarck's and Darwin's respective evolutionary theories. Comparing three accounts of evolution was also the teaching design in (Ford & Wargo, 2012). The contribution from this study (Paper 1) is the description of the three conversational structures concurrent in the classroom communication in which the teacher makes conceptual distinctions between the explanations and clarifies differences in order to facilitate students' learning and understanding.

Another of the activities that students are supposed to employ is to draw their own conclusions, make predictions, and provide causal explanations in relation to the evolution of different organisms and particular traits. Other studies have shown how students learn how to use words and ideas in discussions, for example, about adaptations that fit particular environments (Ash, 2008; Olander, 2009). What this study shows is the progression in teacher's query constructions (Paper 2) and the strategies for link-making (Paper 3) that provide communicative structures for developing students' understanding of key concepts, and abilities to draw their own conclusions and construct their own explanations.

In order to provide opportunities for learning about biological evolution, important teacher tasks in this classroom are to maintain the appropriate modes of reasoning, and to coordinate language use, student participation and topics so that patterns are formed. The teacher repeatedly indicates what to take into account, how to carry out the reasoning and give the necessary explanations in relation to the focused topics. Important student tasks are to co-construct patterns of communication, for example to distinguish how to use language, participate in different activities, and connect narrow topics in

individual lessons to wider topics in a sequence of lessons. The contribution from this study is how some of these activities are fitted together.

Link-making

One of the mutually communicative *and* cognitive activities employed in this classroom is link-making. The notion of link-making has been used in different ways. For instance, pedagogical link-making (Scott et al., 2011) conceptualises science teaching strategies, and Haug and Ødegaard (2014) point to the function of link-making for students' progression in word knowledge and conceptual understanding. In this project, link-making is primarily conceptualised in relation to temporal aspects of communication, that is, how the teacher and the students construct connections and links along a time dimension. When the teacher and the students make associations, pose questions and in other ways make connections between different conversations, mutual understandings of particular topics, such as how survival and extinction of different species come about, appear momentarily in the flow of classroom communication. This is a significant result because it shows how a science teacher gradually organises and develops certain topics in the classroom communication. This might imply that in single episodes the teacher postpones issues or ignores certain questions from the students in order to focus on students' understanding of a key concept or principle. This has implications for research design and underlines the importance of multi-scale approaches for understanding the purposes of teaching on many timescales. One methodological advantage of a temporal conceptualisation of link-making is that the temporal instances of link-making are distinct and make way for a precise coding procedure, which can be used to develop the concept of link-making further.

Cognitive practices

The activities employed by the teacher and students in this classroom can be compared to the sets of promoted processes that Bloome et al. (2009) find in their study of a language arts classroom: to employ retrieval, comparison and contrast, and synthesis. Adjusting to various communicative and cognitive activities, as students are expected to, is demanding. Going from one lesson to another literally means leaving and entering communicative and cognitive practices of different kinds in a couple of minutes. For policy makers and for curricula and school planners, it is important to be aware that the reality of

teaching and learning in a school subject cannot be understood by looking only at schedules, curricular units, and their respective time-frames, but that knowledge about teacher-student interaction and classroom practices are essential background information with regard to conditions in school when teaching and learning outcomes are evaluated.

A multi-scale approach

One of the main contributions from this project is that it shows some affordances of conducting classroom research on multiple scales. In the literature the potential of multi-scale approaches are discussed (Lemke, 2000; Mercer, 2008; Molenaar, 2014; Roth et al., 2008) and the particular importance of multi-scale analyses for enhancing the understanding of teaching and learning of content has been pointed to (Klette, 2007).

Dimensions of time

Molenaar (2014) describes two dimensions of time represented in research: first, a dimension of time as individual events within the flow of events. This describes for example studies using the framework of Mortimer and Scott (2003) for investigating the interactional organisation of individual lessons or that of Sahlström and Lindblad (1998), which analyses how the sociocultural ecology is defined in the situation. The second dimension of time represented in research, according to Molenaar, is time as relative arrangements of multiple events. This is, for example, what trajectories describe, such as interaction trajectories in Furberg and Ludvigsen (2008) or topic trajectories in this study (Paper 3). In this project, it is the combination of dimensions of time that determines this particular option for making visible a range of possible events contained within the activity pattern of this classroom.

Macro and micro processes

For Molenaar (2014), research connecting different levels of analysis shows how phenomena at the macro-level can arise from and be constrained by dynamics at the micro-level. In the study of student participation (Paper 2), it was the analysis of many instances on the micro-level, of student interaction in small-groups and the teacher's actions when leaving the front position in the classroom that opened up for conclusions regarding the macro-level: the function of repeated small-group activities in the sequence of lessons. The

activity pattern with repeated small-group activities represents one phenomenon at the macro-level and students' knowing and not knowing positions represent dynamics at the micro-level, which turns out to constrain the students' and the teacher's actions. The activity pattern is a significant result that gives insight into the practical concerns of a science teacher. In Paper 1, the three potential meanings of the word explanation arise from the conversational structures and interaction at the micro-level. In Paper 3 short exchanges about the survival and extinction of species show how questions about this theme develop. The result from this project illuminates some challenges involved in science teaching and learning (co-existing word meanings, different paces of students' participation, complex (biological) explanations). Some of these challenges arise from patterns in the details of interaction and constrain the teaching and learning. This has implications for decisions on how to make improvements in teaching.

An arena for communication

Another contribution from this project is that it explores possibilities for using dialogical theories of communication for the understanding of science classroom communication. The communication in science classrooms has been one focus in the literature (Kress, 2001; Lemke, 1990) and particular frameworks for its analysis have been developed (Mortimer & Scott, 2003).

A unique configuration

The descriptions of how the teacher makes conceptual distinctions regarding the word explanation, how the classroom is organised, and how the teacher and students make connections between lessons, make up a specific configuration during this unit of description. This is a description of a science classroom that contrasts with the descriptions by Lemke (1990) and Mortimer and Scott (2003). Lemke describes, for example, a classroom where the teacher strictly regulates the right to speak, and Mortimer and Scott explain the coordination between teacher and students using four communicative approaches.

The results from this project describe a lesson structure in the unit, classroom activities, participant roles, topic progression, and traditions of language use. These are parts of communicative structures found in the empirical material that can be confirmed theoretically, and some of the events

that occur in the classroom are established analytically in the relations between them. Mortimer and Scott (2003) develop the idea that the four communicative approaches are distinct in classroom communication and that these approaches can be combined in certain ways for the purpose of establishing patterns productive for science teaching and learning. The current project describes the coordination between teacher and students in relation to an activity pattern. The analytic focus on activity patterns implies studying classroom interaction in relation to different classroom activities and transitions between activities.

A reasoning science classroom?

The investigated classroom is a type of science classroom in which reasoning, explaining, and communicating are emphasised. Some of the characteristics of this type of classroom have been discussed: correct answers are not the only contribution from students in the classroom - on the contrary, reasoning and explaining are important classroom activities; not only the teacher's voice is heard, students also participate - for example it is legitimate for students to initiate new communicative projects. In their study of six Norwegian science classrooms, Ødegaard and Klette (2012) find a less authoritative science teaching in comparison to what previous studies have described. Their description of science teaching has parallels with this project. Lemke (2000) describes emergent processes in classrooms:

> A classroom, and indeed every human community, is an individual at its own scale of organization. It has a unique historical trajectory, a unique development through time. But like every such individual on every scale, it is also in some respects typical of its kind. That typicality reflects its participation in still larger-scale, longer-term, more slowly changing processes that shape not only its development but also that of others of its type. (Lemke, 2000, p. 278)

Seen in the light of what Lemke (2000) describes, the results from this project suggest a type of classroom evolving through emergent processes in science teaching. According to the results and what was observed in the classroom in this study, these emergent processes imply that students participate in the classroom discourse, that teaching emphasises reasoning activities, and that learning science means developing certain reasoning skills. A designation like 'reasoning science classroom' suits the classroom described here and other classrooms of that kind.

Implications for science teaching in school

In the Swedish curricula between 1994 and 2011, students' reasoning skills are increasingly emphasised (National Agency for Education, 2000, 2006, 2008, 2011). In relation to this the results from this study raise a serious issue. This study demonstrates the complexities of a science classroom in which students participate and reason and in which many communicative projects are legitimate. It might be the case that in such a classroom the communication becomes so complex that it becomes difficult for the teacher to maintain the appropriate modes of reasoning, to coordinate language use, student participation and topics so that patterns are formed. In that case it is a very difficult task to learn how to participate in different activities, how to distinguish how to use language in appropriate ways, and how to connect narrow topics to wider topics. There may be many reasons behind the emphasis on developing students' communicative skills (such as for example reasoning skills in school science), but this has consequences for the conditions for teaching and learning. This study shows some challenges for science teachers and students.

For groups working to improve science teaching and learning, the communicative patterns described in this project have the potential to contribute insight into conditions prevailing for science teaching in school, as well as an increased awareness of the communicative challenges involved. First, it could be pointed out that the language resources used in science classrooms are derived from traditions in the science disciplines, from school traditions and from everyday life. Second, this project shows different paces of student participation that have major implications for opportunities for learning provided in classrooms. Third, the study illuminates a fragmented practice consisting of eleven fifty-minute occasions over four weeks, in which work from the teacher and the students is required in order to connect lessons into comprehensible units. An increased awareness of these issues is primarily for the benefit of science teachers, students, and teacher educators.

More generally the project suggests some patterns and some alternative ways of understanding the work of science teachers and students. Some implications are questions for discussion in relation to science teaching: how classroom organisations allow evolving participation frameworks, how the making of conceptual distinctions is enabled in the communication, and how the teacher and students facilitate connections between lessons.

Limitations and future research

Even if there are resemblances between this classroom and other classrooms, each classroom practice is unique. The description that is the result of this project is only one possibility among numerous other ways of responding to the same purpose. The patterns described here are justified empirically and are also developed in relation to a particular theoretical framework. Dialogism is a broad framework with many options for the development of analytical approaches. Analytical tools within the framework direct the analysis towards definitions of social interaction. Among the limitations are the scarceness of opportunities to relate to the disciplinary field associated with and represented in the form of teaching and learning of a school subject. This will also make it difficult not only to address questions of effectiveness (which is important in some research traditions) but also questions of the relevance of classroom activities with respect to learning in science. For those who ask evaluative questions regarding the effectiveness of teaching and learning, this project provides no answers and this might be perceived as a limitation. This is a deliberate choice in order to facilitate the analytical perspective on the activities in which students participate and reason.

Further research is needed in order to understand more aspects of science classroom practices and communication. This study – together with other studies of other aspects in other science classrooms – contributes to the comprehension of the multitude of various science classroom practices and the complexities involved. Future studies made in other classrooms can contribute important patterns complementary to the patterns described here.

Conclusions

This project shows that it is possible to analyse and describe aspects of the formation of a science classroom. Critical for the development of this project was the multi-scale approach, which was enabled by the theoretical framework. The analysis of word meaning in the classroom in relation to the three traditions of using language in everyday life, science disciplines and school was for example made possible by the theoretical framework, the dialogical principles, and the CAT-analysis (Linell, 2009a). This study describes some of the empirical dimensions that form science lessons as a type of communicative activity. It is possible to make other investigations of the same classroom material using other approaches or empirical dimensions,

and come up with other complementary patterns. With the help of the CAT-analysis (see Table 1), the present approach can be compared with other studies of science classroom communication.

Another conclusion from this study is the significance of coordination for the science classroom practice. The coordination is, in this project, illustrated by three aspects: making of conceptual distinctions, classroom organisations, and connections between lessons. This study has shown how the teacher (and the students) in this particular classroom coordinate:

- the use of language in the classroom in relation to the traditions of science disciplines, school and everyday life, exemplified by the word explanation
- the progression in a curricular unit and the pace of students' participation by repeated use of small-group activities
- the time-frames for particular topics in a sequence of lessons using different link-making strategies

Understanding the unique configuration of this classroom entails all these intertwined dimensions in combination with the ongoing teaching and learning activities. This conclusion points towards the value of making use of multi-scale approaches in the further exploration of (science) classroom practices. This thesis contributes results that are relevant on different levels of generalisation. It shows the teacher's and students' strategies for negotiating and contextually defining the content (biological evolution). The thesis also shows that these communicative processes extend in time and are not isolated instances. The empirical results show the use of reasoning strategies, the construction of paths or trajectories that reflect learning opportunities and meaning-making in the classroom, as well as the coordination between communicative practices represented in science, school and everyday life.

8 Summary in Swedish

Samtal i ett naturvetenskapligt klassrum

Det här är en svensk sammanfattning av några centrala delar i avhandlingen *Reasoning in a Science Classroom*. Sammanfattningen beskriver det övergripande angreppssättet och något av den tidigare forskning som är relevant för studiens syfte. Här sammanfattas de tre ingående delarbetena och deras resultat.

Syfte och utgångspunkter

Avhandlingen är skriven utifrån forskningsintresset att undersöka och bättre förstå interaktionen mellan lärare och elever vid undervisning och lärande om naturvetenskapliga innehåll. Syftet är att identifiera och beskriva tre aspekter av verksamheten i ett naturvetenskapligt klassrum: hur distinktioner görs mellan begrepp, sätt att organisera klassrummet och hur kopplingar görs mellan lektioner. Med detta tredelade syfte analyserar den här studien ett empiriskt material som består av elva videoinspelade lektioner om biologisk evolution.

Biologisk evolution är ett ämnesinnehåll som är känt för de utmaningar det innebär för undervisning och lärande (Smith, 2010b). Det kan också, för en del lärare och elever, vara ett utmanande innehåll i relation till frågor om världsbilder och tro (Smith, 2010a). Biologins förklaring av livets evolutionära utveckling beskriver långa tidsperspektiv och konsekvenser på olika organisationsnivåer, som den genetiska-, cellulära-, organism- och populationsnivån. I den biologiska förklaringen kopplas flera begrepp samman som vart och ett har sina egna komplexa betydelser, några exempel är begreppen *anpassning*, *population*, och *selektion* (Kampourakis, 2014; Rosengren, 2012).

Tidigare forskning

Forskning om det naturvetenskapliga klassrummet

Det naturvetenskapliga klassrummet har tidigare studerats inom det internationella fältet *science education,* inom traditioner för klassrumsstudier och forskning om lärande (Ford & Forman, 2006; Klette, 2007). Forskningen utgår från en mängd teoretiska perspektiv, med skilda metodologiska angreppssätt och synsätt på kunskap och lärande. Två exempel på skilda teoretiska perspektiv är dels den forskning som utgår från modellen *conceptual change* (Posner et al., 1982), dels studier av klassrummets triadiska dialoger, det vill säga: mönster av lärares frågor, elevers svar, följt av lärarens utvärdering (Mehan, 1979; Sinclair & Coulthard, 1975). Det första perspektivet utgår från en syn på individuell kunskapsutveckling medan det andra perspektivet utgår från en syn på kunskap som socialt konstruerad. En majoritet av den forskning som bedrivits har inte tagit hänsyn till de olika tidsdimensioner som undervisning och elevers kunskapsutveckling sker inom, vilket är något som har efterfrågats i litteraturen (Lemke, 2000; Mercer, 2008; Roth et al., 2008). Även om det finns ett ökat intresse för frågor om temporalitet behöver forskningen också utveckla teoretiska och metodiska angreppssätt (Molenaar, 2014). Den här studien visar ett möjligt angreppssätt för att förstå hur en del av det som kännetecknar en serie lektioner manifesteras i detaljer av specifika situationer i klassrummet.

Ett fokus för tidigare forskning har varit den särskilda kommunikation som sker vid undervisning och lärande av naturvetenskapligt innehåll (Kress, 2001; Lemke, 1990; Mortimer & Scott, 2003; Ogborn, 1996). Ett betydelsefullt bidrag är Lemke (1990) som visar komplexiteten i de tematiska mönster som eleverna ska lära sig i det studerade klassrummet. Han drar slutsatsen att lärande i naturvetenskap innebär att lära sig att kunna tala med ett naturvetenskapligt språk. Ogborn (1996) och Kress (2001) visar hur det laborativa arbetet, både i form av lärarens demonstrationer och i form av elevens praktiska arbete med experiment, likaväl som andra multimodala inslag, har viktiga roller att spela för ”det naturvetenskapliga klassrummets retorik”[11] (Kress, 2001). Det analytiska ramverk som utvecklas i Mortimer och Scott (2003) utgår från fyra sätt som lärare i naturvetenskapliga ämnen tar sig

[11] Min översättning, titeln i original: ”Multimodal teaching and learning: the rhetorics of the science classroom” (Kress, 2001).

an kommunikationen med eleverna[12]. Detta ramverk används för att analysera lärares strategier att växla mellan att dels förevisa de rätta svaren, dels resonera sig fram mot lösningar och samtidigt antingen tillåta eller inte tillåta grader av elevinteraktion. Aguiar et al. (2010) visar att i ett klassrum där elever deltar i resonerande samtal sker en ständig förhandling om vad innehållet betyder och hur det kan förstås. Den här studien tar sin teoretiska utgångspunkt i dialogiska teorier om kommunikation. Det är ett ramverk som möjliggör en analys av hur läraren och eleverna i det här klassrummet orienterar kommunikationen mot ämnesinnehållet och hur innehållet manifesteras i detta samspel.

Forskning om klassrumsinteraktion

Inom fältet *science education* finns ett ökat intresse för klassrumsinteraktion (Fraser et al., 2012; Roth, 2010). Ett antal senare publikationer uppmärksammar hur elever och lärare orienterar sig mot det naturvetenskapliga innehållet i klassrumsinteraktionen. För att göra det fokuserar de vissa händelser i klassrumsverksamheten och utvecklar ramverk för att benämna det som sker. Några exempel som är av relevans för den här avhandlingens syften redovisas nedan.

Lidar et al. (2006) undersöker hur elever socialiseras in i de normer som gäller en naturvetenskaplig klassrumspraktik i ett sammanhang av kemilaborationer. Kaartinen et al. (2002) gör en intervention och undersöker hur universitetsstudenter som läser kemi konstruerar förklaringar under grupparbete om löslighet. Krange (2007) studerar en grupp elever och deras lärare när de arbetar med en datormodell av en gen som kodar för ett visst protein. Lehesvuori et al. (2013) använder ramverket från Mortimer och Scott (2003), som kort beskrivits ovan, och spårar hur fyra kommunikativa strategier avlöser varandra under olika lärares undervisning om elektricitet och energi. Xu och Clarke (2012) kartlägger hur elever använder sig av både konceptuella och fysiska artefakter när de bygger en pendel under en fysiklektion. Det som förenar dessa studier är den lokalt definierade kontexten samt nya sätt att begreppsliggöra den både kognitiva och kommunikativa verksamhet som just lärande och undervisning om naturvetenskap innebär.

[12] Mortimer och Scott (2003) använder begreppet *communicative approach*

Teoretiskt och metodologiskt angreppssätt

Avhandlingens metodologiska utgångspunkter vilar mot en bakgrund i dialogiska teorier om kommunikation (Linell, 2009a). I sin dialogism sammanför Linell dialogiska teorier från många discipliner genom att utreda de perspektiv, distinktioner och antaganden som är gemensamma. På detta sätt ger Linell en teoretisk grund för utvecklingen av analytiska angreppssätt samtidigt som ramverket är brett och inkluderar många riktningar. Några centrala delar är de tre dialogiska principerna, synen på det talade språket och på lärande.

Tre dialogiska principer

Dialogiska teorier betraktar människors meningsskapande som något som definieras i kontexten, och sker i samspel med andra. Det ger dels ett historiskt perspektiv på språket som format av traditioner för kommunikation dels ett perspektiv på det enskilda yttrandet i ett samtal. De tre dialogiska principerna – det ömsesidiga beroendet mellan handling/yttrande och verksamhetstyp (*act-activity interdependence),* sekventialitet och gemensam konstruktion – är ett sätt att förstå dess uppbyggnad. Principen för det ömsesidiga beroendet mellan handling/yttrande och verksamhetstyp (*act-activity interdependence)* beskriver hur varje yttrande ses i relation till den aktivitet som det är en del av. Principen för sekventialitet beskriver hur meningen av ett yttrande delvis är bestämd av dess position i relation till andra yttranden. Principen för gemensam konstruktion beskriver hur deltagarna koordinerar interaktionen så att samtalet blir utfört gemensamt. De tre dialogiska principerna användes här som utgångspunkt för utvecklandet av flera sätt att analysera klassrumsinteraktion under de elva lektionerna.

Videofilmat klassrumsmaterial

Vid sidan av de dialogiska teorierna för kommunikation var också beslutet att basera studien på analyser av videoinspelat klassrumsmaterial betydelsefullt. Genom en sofistikerad teknisk design med flera simultana kameror och mikrofoner (Clarke et al., 2009) kunde klassrumsinteraktion på detaljnivå dokumenteras. Studien undersöker ett klassrum där en lärares undervisning om evolution sker under elva lektioner i en klass 9 (15 år gamla elever). Det empiriska materialet innefattar 38 timmar video från fyra kameror. En kamera fokuserade det läraren gjorde och sa, vilket transkriberades på ordnivå i sin

helhet (570 minuter). Två kameror fokuserade arbetet i två elevgrupper, och deras samtal transkriberades i delar med fokus på arbetet med gruppuppgifter (200 minuter).

Elva lektioner om biologisk evolution

De elva lektionerna utgjorde den samlade undervisningen i området evolution i skolämnet biologi och karaktäriserades av en hög grad av elevdeltagande. Under den första lektionen fick eleverna möjlighet att associera fritt kring termer som evolution och genetik och sedan gruppvis skriva ned sina förklaringar till den evolutionära uppkomsten av giraffens långa hals. Dessa texter återkom under serien av lektioner och diskuterades bland annat i relation till tre historiska modeller av evolution. Undervisningen dominerades av helklassundervisning men fyra av lektionerna genomfördes i halvklassgrupper. Under dessa lektioner lades största delen av tiden på utförandet av praktiska uppgifter. Vid första tillfället arbetade eleverna med varandras texter och vid det andra tillfället arbetade de med att beskriva och sortera bönor. Innehållet i de elva lektionerna gav historiska perspektiv på hur teorier om evolution utvecklats inom vetenskapen, genomgång av centrala begrepp samt många möjligheter för samtal och reflektion kring ämnesinnehållet.

Tre delarbeten

Studien innehåller tre delarbeten som analyserar det som sker under de elva lektionerna genom att fokusera kommunikationen i klassrummet.

Delarbete 1 The many roles of "explanation" in science education: a case study

Delarbete 1 innehåller en analys av de 98 tillfällen då läraren använder ordet *förklaring* eller liknande konstruktioner (som *förklara*, *förklaringen*, *förklarade*) i klassrummet. Syftet är att undersöka vilka konsekvenser olika betydelser av *förklaring* har för kommunikationen. Resultaten visar att under de elva lektionerna används de fokuserade orden bland annat för att uppmuntra och utmana eleverna att göra uppgifter, och för att hjälpa eleverna att utveckla kunskaper om hur förklaringar kan utvärderas och bedömas. I genomförandet av klassrumsaktiviteter iscensätter läraren tre samtalsstrukturer där orden förekommer. Det är när läraren efterfrågar en förklaring, när läraren tillsammans med eleverna samtalar om vad en förklaring är i den aktuella

undervisningskontexten, och när läraren tillsammans med eleverna samtalar om elevernas sätt att förklara. Analysen visar att flera meningsbetydelser av ordet *förklaring* samexisterar i kommunikationen i klassrummet. Vid ett tillfälle diskuterar läraren tre historiska modeller för att förklara den biologiska evolutionen: den bibliska skapelseberättelsen samt de två evolutionsteorier som Lamarck och Darwin formulerade. I detta samtal behandlas den bibliska skapelseberättelsen både som en typ av förklaring, samtidigt som läraren, genom att använda gester och peka på skillnader i grundantaganden, tydligt visar att det är en förklaring som inte är relevant i sammanhanget. Vid ett annat tillfälle uppstår ett samtal om hur eleverna i sina försök att förklara giraffens evolution blandar inslag från Lamarck och Darwin. Samtalet behandlar ordet *förklaring* omväxlande i en vardaglig mening: som något som bidrar till en ökad orsaksförståelse om varför livet har utvecklats, och i en pedagogisk-professionell mening: som en kausalt uppbyggd händelsebeskrivning av hur livet har utvecklats. Beskrivningen av de tre meningsbetydelserna av ordet *förklaring* (en vardaglig, en pedagogisk-professionell, och en vetenskaplig) och deras samexistens i det naturvetenskapliga klassrummet möjliggör ett tydligare bruk av ordet både i forskning och klassrumsverksamhet och kan i båda fallen bidra till förbättrad kommunikation och fördjupad förståelse.

Delarbete 2 The temporality of participation in school science: Coordination of teacher control and the pace of students' participation

Delarbete 2 innehåller en analys av hur aktiviteter i klassrummet är koordinerade i ett samspel mellan lärarstyrning och elevdeltagande. Syftet är att undersöka hur olika sätt att delta i klassrummet avlöser varandra och hur detta regleras till exempel i övergångar mellan helklassgenomgång och smågruppsdiskussion och i serien av lektioner. Analysen visar detaljerna i det samspel som sker och hur läraren upprepat lämnar och återtar frontpositionen i klassrummet. Det ger utrymme åt eleverna att arbeta tillsammans och läraren får möjlighet att samtala och ställa frågor till grupper av elever om hur de förstår det aktuella ämnet. I delarbetet pendlar analysen mellan ett övergripande perspektiv på lektionssekvensen och mikroanalyser av samtal mellan elever eller mellan elever och läraren. Progressionen i ämnesinnehållet utgör en del i regleringen av det undersökta klassrummets organisation och de frågekonstruktioner som läraren använder uttrycker en ökad komplexitet för serien av lektioner. Den ökade komplexiteten är väntad också av eleverna och

är därför en del av det koordinerade samspelet. Analysen ger möjligheten att omtolka och förstå smågruppsdiskussionerna främst som något läraren använder sig av för att anpassa elevernas deltagande till ett gemensamt tempo för undervisningen. När läraren lyfter upp frågor från smågruppsdiskussionerna till helklass behövs endast en symbolisk återkoppling eftersom läraren då övergår till att förklara det centrala i frågeställningen. I delarbete 2 synliggörs skillnader mellan grupper av elever och deras deltagande i klassrummets aktiviteter.

Delarbete 3 A topic trajectory about survival: analysing link-making in a sequence of lessons about evolution

Delarbete 3 innehåller en analys av hur läraren och eleverna knyter samman samtal med varandra, till exempel mellan lektionerna i ämnesområdet. Syftet är att undersöka hur läraren och eleverna åstadkommer en mängd samband mellan innehåll och samtal genom undervisningssekvensen om evolution. Analysen synliggör de strategier för att länka samtalsinnehåll som eleverna och läraren använder under de elva lektionerna. En analytisk modell används för att förstå länkning mellan nivåer i undervisningen. Länkning avser konkreta hänvisningar som görs mellan samtal, det kan t ex vara läraren som hänvisar till det som hände på lektionen innan eller en elev som hänvisar till något som sagts tidigare, kanske inom ramen för samma lektion. Analysen visar hur länkning mellan lektioner bidrar till att knyta samman ämnesinnehållet. I delarbete 3 visas detta genom fyra situationer där frågor angående arters överlevnad eller utrotning ställs. Ett annat sätt att använda länkning visar läraren då vissa samtalsämnen skjuts till framtida lektioner för att upprätthålla agendan för den aktuella lektionen. Länkningar till andra skolämnen och andra områden i biologi representerar något som binder samman dessa elva lektioner med andra lektioner, ämnen och verksamheter i skolan. Länkningar inom lektioner handlar om när eleverna ställer frågor om något som precis har sagts eller associerar till och kommenterar andra samtal om samma eller liknande innehåll. Delarbete 3 visar att både lärare och elever länkar mellan samtal och på detta sätt bidrar till kontinuitet och koherens i den annars fragmentariska klassrumsverksamheten.

Resultat och diskussion

Att föra resonemang om evolutionära processer

Resultaten från den här studien beskriver ett klassrum där undervisningen och lärandet om biologisk evolution sker genom en form av resonerande samtal som förs både i helklass och i smågrupper. De resonerande samtalen behandlar frågor som, t ex: Vad var det som fick vissa arter att överleva? Hur uppkom den första levande cellen? och Hur går det att avgöra om en egenskap kan överföras till avkomman eller om den inte kan göra det? I det undersökta klassrummet förväntas eleverna inte bara kunna besvara sådana frågor, utan lära sig att resonera om dem i termer av evolutionära processer på sätt som är avsedda inom ämnet biologi i högstadiet. Under lektionerna ska eleverna bland annat jämföra och utvärdera tre olika förklaringar till evolutionen: bibelns skapelseberättelse, samt Lamarcks och Darwins respektive evolutionsteorier. Eleverna ska också dra egna slutsatser och göra antaganden om orsaker till och konsekvenser av biologisk variation. Evolutionsundervisning har studerats tidigare, t ex beskriver Ford och Wargo (2012) också en undervisning som utgår från skillnader mellan tre historiska förklaringar av evolutionen och Ash (2008) och Olander (2009) analyserar elevdiskussioner om arters egenskaper och anpassning i relation till evolutionär utveckling. Det den här studien specifikt bidrar med är att visa hur de olika aktiviteterna koordineras i klassrummet: genom de samtalsstrukturer som används och synliggörs i delarbete 1, genom progressionen i frågekonstruktionerna som synliggörs i delarbete 2 och genom länkandet mellan olika aktiviteter som synliggörs i delarbete 3. Lärarens sätt att i det här klassrummet resonera, att använda ord och uttryck, att ge ramar för elevernas deltagande och ämnesinnehållet etc, innebär att mönster skapas och ger förutsättningar för lärande om biologisk evolution. Läraren upprätthåller mönstren i kommunikationen med eleverna genom att återkommande hävda dessa ord och uttryck och sätt att resonera. Elevernas deltagande bidrar till att befästa dessa mönster: de förväntas exempelvis urskilja hur ord och uttryck ska användas, veta hur de ska delta i aktiviteter och koppla samman detaljer och helheter.

Ett flerskaligt angreppssätt

Ett av studiens bidrag är att den visar möjligheter med ett flerskaligt angreppssätt i klassrumsforskning, alltså en undersökning av de både korta

och långa tidsdimensioner som lärande och undervisning verkar inom. Molenaar (2014) beskriver två sätt att representera tid inom utbildningsvetenskaplig forskning. Det görs dels i form av att studera enskilda händelser i en ström av händelser, dels genom att studera en serie händelser och fastställa hur de relaterar tidsmässigt till varandra. När forskning kopplar samman analyser på skilda nivåer (över många lektioner eller i detaljer av händelser) kan samband mellan dem upptäckas, enligt Molenaar (2014). I den här analysen är det kombinationen av tidsdimensioner som bidrar till att belysa ett antal möjliga händelser i just det aktuella klassrummet. Det var exempelvis genom att analysera många tillfällen av interaktion, både mellan elever, och mellan läraren och grupper av elever, som funktionen med de återkommande smågruppsaktiviteterna i de elva lektionerna blev tydlig. Resultatet från den här studien visar att detaljer i samspelet mellan elever och lärare i vissa fall kan belysa större skeenden i klassrummet. Det görs genom att synliggöra vissa situationer och därmed ett antal kommunikativa utmaningar som ingår i naturvetenskapligt lärande och undervisning, till exempel: samexisterande meningsbetydelser, de skilda sätt på vilka elever deltar i klassrumsaktiviteter med naturvetenskapligt innehåll, och den komplexitet det innebär att samtala om biologiska förklaringar till livets evolution.

Kunskap och kommunikation i en naturvetenskaplig klassrumspraktik

Den här studien undersöker hur dialogiska teorier för kommunikation kan användas för att förstå den speciella kommunikation som kännetecknar undervisning och lärande om naturvetenskap. Resultaten är unika för det undersökta klassrummet och de elva lektionerna som analyserats, och ger en annan beskrivning av ett naturvetenskapligt klassrum än exempelvis de tematiska mönster i det lärarstyrda klassrum som beskrivs i Lemke (1990) eller hur undervisningen kan förstås genom lärares fyra kommunikativa strategier som beskrivs i Mortimer och Scott (2003). Den här studien visar ett antal kommunikativa strukturer i det empiriska materialet, i vissa fall sammankopplade, som också kan bekräftas teoretiskt. Serien av elva 50-minuters lektioner, de återkommande smågruppsaktiviteterna, lärarens och elevernas olika roller för deltagande, ämnesprogressionen och de tre traditionerna för språkanvändning (en vardaglig, en pedagogisk-professionell, och en vetenskaplig) är fem strukturer för klassrummets kommunikation som kan jämföras med resultat från andra studier av denna kommunikativa verksamhetstyp (se Tabell 1, sid 47) (Linell, 2009a). Ødegaard och Klette

(2012) studerar sex klassrum med naturvetenskaplig undervisning i Norge och konstaterar att undervisningen har karaktären av att vara auktoritär i lägre grad än vad de finner beskrivet i tidigare studier. Den beskrivning som görs i deras studie har paralleller med den här studien och den undervisning som studeras här. Det är ett klassrum där elevernas deltagande i resonerande samtalsaktiviteter är betonat och där att lära sig naturvetenskap innebär att kunna delta i sådana aktiviteter.

Slutsatser

Syftet med avhandlingen är att identifiera och beskriva tre aspekter av verksamheten i ett naturvetenskapligt klassrum: hur distinktioner görs mellan begrepp, sätt att organisera klassrummet och hur kopplingar görs mellan lektioner. Genom att analysera dessa aspekter och peka på samband mellan detaljer i klassrumsinteraktionen och mönster i kommunikationen som uppstår över flera lektioner bidrar resultaten från denna studie, tillsammans med andra studier, som exempelvis Ford och Forman (2006) och Mortimer och Scott (2003), till en förståelse av de kunskapsuttryck, kommunikationsmönster och kommunikativa situationer som finns inom ramen för det naturvetenskapliga klassrummet. Det undersökta klassrummet är en typ av klassrum där resonerande samtal och kommunikation mellan lärare och elever i allmänhet är betonade aktiviteter. Resultaten av den här studien synliggör vikten av att koordinera klassrumskommunikationen då elever ges möjlighet att delta, så att mönster uppstår och ger förutsättningar för lärande. Slutligen visar den här avhandlingen ett sätt att använda dialogiska teorier för att förstå klassrummet som en arena för kommunikation och några av de villkor detta ger för den undervisning och det lärande som sker.

Appendix

GÖTEBORGS UNIVERSITET
UTBILDNINGSVETENSKAPLIGA FAKULTETEN

Medgivande till medverkan i en forskningsstudie om lärande och undervisning

Under de närmaste veckorna kommer ett forskningsprojekt att genomföra en studie i din klass. Projektet bedrivs av forskare vis Göteborgs universitet i samarbete med forskare från Australien. Projektledare är och i projektgruppen ingår också

Projektets syfte är att förstå mer om lärande och undervisning av naturvetenskap. Vi vill få kunskap om hur elever lär naturvetenskap så att undervisning kan utvecklas och ge förutsättningar för att elever ska förstå och bli intresserade. Vi kommer att videofilma i klassrummet och intervjua både elever och lärare. Inspelningarna kommer sedan att användas i forskning med fokus på lärande och undervisning i naturvetenskap.

Allt arbete inom projektet kommer att ske i enlighet med Personuppgiftslagen (1998:204). Inspelningar kommer att förvaras på sätt som innebär att obehöriga inte kan få tillgång till dem. De personer som medverkar på videoinspelningarna kommer att vara anonyma i den rapportering som kommer ut av projektet. Namn kommer att ändras till fiktiva namn i de texter som publiceras av projektet. Om bilder från videoinspelningarna används vid rapporteringar kommer även de att anonymiseras så att personerna inte är möjliga att känna igen.

Deltagandet i videoinspelningarna är frivilligt och medverkande kan när som helst välja att avbryta sitt deltagande. Meddela i talongen nedan om du vill delta eller inte.

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