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Teaching and Learning in Lower Secondary Schools in the Era of PISA and TIMSS

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Chapter 1
Introduction: Studying Interaction and Instructional Patterns in Classrooms

Kirsti Klette

> *Classrooms are complex places, and the best teachers are successful because they are thoughtful opportunists who create instructional practices to meet situational demands.*
>
> *(Duffy and Hoffman 1999)*

This book explores teaching and learning in lower secondary classrooms in the three PISA domains: science, mathematics, and reading. Based on extensive video documentation from science, math and reading classrooms, we discuss and explore how offered and experienced teaching and learning opportunities in these three subject areas contribute to student learning.

How to improve teaching and instruction has become a key priority in many countries in the last decade, and recent reviews (McKenzie et al. 2005; Seidel and Shavelson 2007; Timperley and Alton Lee 2008; Hattie 2009; Hanushek and Woessmann 2011) indicate that teaching practices do make a difference to students' learning, and are more important than other factors including students' socioeconomic background, class size, classroom climate, and teachers' formal training and experience. Up to now, research in the field has been slow due to competing theoretical and methodological paradigms, and there is a need to go behind the general achievement patterns and open the black box of teaching and learning practices in secondary schooling. Video documentation has proven especially powerful in the investigation of teaching and learning (Hiebert et al. 2002; Clarke et al. 2006; Seidel and Prenzel 2006; Klette 2009) as it enables more precise, complete, and subtle analyses of teaching/learning processes. Video supports both qualitative and quantitative analyses of teaching/learning processes and thus could serve as common ground that integrates competing camps within the educational sciences. In the field of classroom studies, these could be, on the one hand, large scale studies of teaching effectiveness and, on the other, in-depth micro-genetic studies of specific learning. Fischer and Neumann (2012, p. 115) claim that video

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documentation is especially powerful when investigating teaching and learning 'as it captures students' and teachers' behaviors in the classrooms in one package'. This book is an attempt to start such a discussion on a European basis, using video documentation from Norwegian secondary classrooms as a point of departure.

Norway, and the Nordic countries, as a test bed for discussing contemporary challenges in teaching and learning in secondary schooling are particularly interesting due to their long tradition of national curricula, and unitary and non-streamed structure. In addition, ideas of educational progressivism and student-centered instruction, such as individualized teaching, adapted teaching, and inquiry-based teaching methods, have for a long time been actively promoted within Norwegian educational policies.

In this introductory chapter I will briefly present video documentation as a promising tool for investigating classroom learning, and give an overview of research on instructional quality relevant to the present study. I start out by summarizing research on instructional quality. This summary will serve as an analytical framework and theoretical backdrop for the analyses performed in the following chapters. Then I will discuss video documentation as a tool for understanding classroom learning and elaborate on the types of video design and strategies for data collection and processing that have been essential for the present study. Towards the end of the chapter, I will summarize the goal of this book and present an overview of its sections and individual chapters.

1.1 Research on Instructional Qualities

Research on instruction has revealed complex and significant relations between instructional variables such as teaching quality, cognitive challenge, student engagement, and teacher feedback. Analyses of classroom practices must therefore be sensitive to a range of interactions around instruction, including: the nature of the tasks; the focus of instruction; the features of classroom discourse; the types of accommodations provided; the quality of feedback; support structures, etc.

As indicated, prior research has pointed to multiple dimensions for characterizing classroom interaction, such as the intellectual challenge of tasks assigned to students (Newmann et al. 1998), the quality of instructional conversation (Cobb et al. 2000; Sfard 2000; Cazden 2001; Mortimer and Scott 2003; Seidel et al. 2005; Fischer and Neumann 2012), including teachers' uptake and elaboration of student ideas (O'Connor and Michaels 1993; Nystrand 1997; Sfard et al. 1998), and representations of content (Leinhardt 2004). Studies have further shown that effective teachers are better at allocating more time for academic instruction (Denham and Lieberman 1980; Doyle 1986; Campbell 2004; Roth et al. 2006), as well as at keeping students focused on their tasks. Studies also show that students' motivation and engagement are linked to their achievement, particularly for students in lower secondary education (Guthrie and Wigfield 2000; Roe and Taube 2012). Effective teachers may have more efficient routines for transitioning between activities (Wang et al. 1993; Lipowski et al. 2009) and better classroom management, leading to more time dedicated to instruction (Stigler and Hiebert 1999; Wayne and Youngs 2003; Seidel and Shavelson 2007).

In summary, the four dimensions, *instructional clarity* (clear goals, explicit instruction, content-focused instruction); *cognitive activation* (quality of the task, cognitive challenge, content coverage); *discourse features* (student engagement, quality of teacher–-student interaction); and *supportive climate* (creating an environment of respect and rapport) have proven critical for high-quality instruction. Below, I will elaborate on these dimensions in more depth.

1.1.1 Instructional Clarity

Instructional clarity refers to the degree to which the teacher formulates clear goals for the activity, makes linkages to other related activities, and displays a set of tools for developing metacognitive awareness among the students, such as taking stock, summarizing and reviewing, or 'going over the do now' (Lemke 1990, p. 91). Instructional clarity also covers the degree of explicit instruction, teachers' modeling examples, guided instruction and/or teachers' worked-through examples (Clark and Mayer 2003). In his legacy paper on classroom teaching and learning (entitled *The Cultural Myths and Realities in Classroom Teaching and Learning: A Personal Journey*), Graham Nuthall (2005) claims that students often need three to four *explicit* exposures to the learning material – usually over several days – before any learning can take place. Hattie (2009) uses the term 'visible learning' to frame his argument after researching and synthesizing over 800 meta-analyses on the effectiveness of different teaching strategies. Visible learning, following Hattie, entails teaching strategies such as clear goals, mastery learning, worked examples, use of meta-cognitive strategies, and teachers' skillful use of feedback and assessment strategies. The extent to which these findings contradict basic assumptions of student-centered teaching approaches is debatable. However, the latter have dominated the common understanding of classrooms when these have been transformed into learning communities (Driver et al. 1994; Bransford et al. 2000), and thereby foreground learning rather than teaching. This type of vocabulary often includes an emphasis on student engagement, discovery learning and inquiry-based methods, individualized teaching, and students' independent work.

From the Nordic countries, Emanuelsson and Sahlstrom (2008) and Carlgren et al. (2006) report how student-centered teaching strategies have been foregrounded and privileged over the last few years, with little explicit instruction and teacher modeling as a consequence. Klette (2007) and Dalland and Klette (2012/2014) analyze teachers' instructional practices during students' independent work (individualized teaching in Norwegian terms) in Norwegian secondary classrooms and show how this goes hand in hand with the lack of instructional clarity on the requirements for expected standards of academic performance. From the UK, Alexander (2000, p. 407) discusses how individualized teaching has become the ‘invisible teaching method’, but at the same time, he argues, the knowledge base about individual teaching as a teaching and learning strategy is limited.

1.1.2 Cognitive Challenge

A second feature of high-quality instruction refers to cognitive challenge, that is the intellectual challenge of tasks assigned to students, the cognitive quality of the discussion involved, and the content coverage included. Teachers’ capacity to ‘press for accuracy and build on prior knowledge’, and ‘press for reasoning’ are instructional activities and procedures that connect with high-quality thinking. ‘Revoicing and recapturing’ (“So what I’m hearing you say is . . . ”) or ‘marking’ (“Jenny said something really interesting – we need to think about that”) will also be a part of the teachers’ instructional toolkit to ensure high cognitive challenge. Rigorous thinking is also scaffolded by the teachers’ deliberate use of questioning and discussion techniques and, by their high expectations for students’ performance in explicating their understanding and inferential structure. There is a limited knowledge base about how individual guidance supports students’ rigorous thinking in a productive way. Last but not least, providing sufficient, and thus adequate, time to grapple with the demanding aspects of the task and for expanded thinking and reasoning is critical in order to engage the students with challenging thinking.

Analyses of group work in Norwegian language arts classrooms (see Klette and Ødegaard, Chap. 2) suggest, for example, that the tasks involved were adequately designed and demanding, and so also was the grouping. However, the timeline for solving the task was too generous, and thus served as a hindrance for engaging the students in high-quality thinking. Basically the students were given 20 min to perform a specific task (text-based conversation); however, several of the groups accomplished the assignments within the first 6 min and used the rest of the allotted time for non-academic activities. When the teacher passed by, they argued for yet another 15 min to accomplish the task. Thus, only 6 out of the total 35 min (20 + 15 min) were used for targeted intellectual work.

The TIMSS video science study (Roth et al. 2006; 2009) reveals huge differences in cognitive challenge when comparing lower secondary science classrooms in the US, Australia, Japan, the Netherlands, and the Czech Republic. While students in Czech classrooms, for example, were systematically exposed to challenging talking and learning content through public conversations and targeted classroom work, US students performed a lot of different activities in class – but with low linkages and coherence between the different activities. The US teachers did not typically use these various activities to support the development of content ideas in ways that were coherent and challenging for students (Roth 2009). Using video recordings from mathematics classrooms in Germany and Switzerland, Klieme et al. (2009) demonstrate how high cognitive activation is related to achievement scores in mathematics. The same relationship increased significantly when the supportive climate was taken into account as well (Lipowski et al. 2009). Seidel and Shavelson (2007) found that domain-specific features of instruction and cognitive challenge had the largest effect size when analyzing the effects of teaching on student learning.

1.1.3 Discourse Features

The quality of classroom discourse has long been acknowledged as crucial for students' classroom learning (Alexander 2006; Cazden 2001; Dysthe 1995; Lemke 1990; Mortimer and Scott 2003; Nystrand 1997; Sfard 2000). Discourse features cover elements such as the quality of the instructional conversation in class and teacher–student interaction, as well as the level of student participation and student engagement during class. It conveys teachers' sensitivity to students' ideas and reflections and teachers' uptake and elaboration of those same ideas. Discourse features also covers teachers' capacity to keep everyone together so that they can follow complex thinking (like "What did she just say?" "Can you repeat what Juan said in your own words?") as well as getting students to relate ideas to one another (like "Who wants to add on to what Anna just said?" or "Who agrees and who disagrees with what Anna just said?").

Opportunities for student discussion will also be included in dialogue features in class, that is, teachers provide opportunities for elaborate conversations for at least 4–5 min about a topic between the teacher and students, and among the students.

Analyses of discourse features in lower secondary classrooms in Norway and Sweden suggest a high degree of student participation and student engagement (Emanuelsson and Sahlström 2008; Ødegaard and Klette 2012). However, how these interactional patterns contribute to students' reasoning and achievement scores needs further probing. From analyses of Norwegian lower secondary classrooms, Ødegaard and Klette (2012) report a high degree of student initiatives in science classrooms. To a large extent, these initiatives concern practical and procedural questions, and show poor linkage to making relationships between key concepts and ideas, or exploring high-quality questions. From Swedish mathematics classrooms, Emanuelson and Sahlström (2008, p. 205) discuss the challenge between teachers' control versus students' involvement as 'the price of participation', pointing to the dilemma between, on one hand, teachers' content control and, on the other hand, students' participation. Juswik et al. (2008) discuss dialogic features in language arts classrooms and accentuate how seemingly monologic instruction can optimize the dialogic potential of classroom discourse by opening the floor to student ideas and responding to competing voices. Mortimer and Scott (2003) use the distinctions between authoritative and dialogic, and interactive and non-interactive, to explore communicative approaches in science classrooms in the UK. They argue that any effective teaching lesson should include both dialogic and authoritative discourse, achieved in both interactive and non-interactive ways.

1.1.4 Supportive Climate

Supportive climate refers to the capacity to create an environment of respect and rapport in the classroom, and includes factors such as a supportive teacher–student relationships and positive and constructive teacher feedback. ‘Supportive climate’ refers to how responsive the teacher is to emotional and academic needs, such as providing comfort and encouragement. Supportive climate also includes the extent to which the classroom activities are structured in an orderly way (e.g., classroom management) and the degree to which children’s autonomous behaviors are exhibited. Procedures for supervision and monitoring of student progress might further be a part of a supportive climate. Klieme et al. (2009) add to this list a positive approach to student errors and an ability to support them when they face misconceptions.

However, research findings on the relationships between aspects of classroom climate and student learning are mixed (Brophy 2000, 2004), partly due to differing operationalization of the constructs ‘climate’ and ‘teacher–student relationship’ (Klieme et al. 2009), and partly due to the degree to which classroom management procedures are included in the construct. Seidel and Shavelson (2007) claim that both supportive climate and classroom management should be treated as ‘distal factors’ when trying to understand classroom learning, as they have little *direct* effect on student performance. They have at best an indirect effect on student interest and motivation for learning, the authors argue.

Taken together, these four dimensions (*instructional clarity; cognitive activation; discourse features; and supportive climate)* will serve as lenses when analyzing offered and experienced learning opportunities in Norwegian secondary classrooms. Individually – and together – they provide us with relevant information for understanding the complexities of classroom learning. For such an endeavor, rich data sets that enable us to combine analyses of instructional clarity and content coverage with analyses of teacher–student interaction and dialogue features are required. Video design has a unique position in this respect, as it makes it possible to freeze and scrutinize situations of teaching and learning processes and support multiple analytical ventures when investigating classroom learning. The following section describes the type of video design and data sources underlying this book’s chapters.

1.2 Videos as Lenses for Exploring Classrooms

As already indicated, recent developments in video technology and video documentation have made videos the preferred study design when investigating classroom teaching and learning, and researchers around the world increasingly agree that the advantages of collecting videos of teaching practices can be significant.

In the US, Hiebert and Stiegler (2004) searched for a path that could lead from teachers' classrooms to a shared, reliable knowledge base for teaching, and they argue that video technologies provide an especially useful medium for storing, sharing, and examining knowledge in teaching. They claim that video meets the requirements for how a knowledge base for teaching should look:

- it must be public,
- it must be represented in a form that enables it to be accumulated and shared with other members of the profession, and
- it must be continually verified and improved.

In Australia, Clarke et al. (2006) argue that video documentation supports multifaceted analyses of a commonly held database of teaching, undertaken from different educational and theoretical positions, and "... provide(s) a much richer portrayal of classroom practice than would be possible from any single analysis" (2006, p. 6).

In Europe, Janik et al. (2009) and Klette (2009) demonstrate how video data facilitate fine-grained analyses and re-analyses of patterns and segments of classroom practice, thus making coding procedures and coding more explicit and transparent. At the same time, video data support further analyses, as researchers can always move between the data selected for analyses and the originally collected video data. As such, the researcher can take one step back, Janik et al. (2009) argue, and return to the original video tapes, "...thus avoiding the reduction caused by coding" (p. 13).

Thus, the merits of video documentation are obvious and can be summarized as follows:

– Reveals practices more clearly
– Deepens educators' understanding of teaching
– Enables the study of complex processes
– Stimulates discussion about choices within each instructional practice and context
– Enables coding from multiple perspectives
– Facilitates integration of qualitative and quantitative information
– Stores data in a form that allows new analyses at a later time
– Facilitates communication of results

In summary, video studies have proven to be a valuable tool to investigate instruction on a large scale, as well as on the level of individual teachers. Video analysis allows for identification of context- and subject-specific patterns of instruction, so-called 'cultural scripts' (Stigler and Hiebert 1999, p. 9), and/or discourse features and interaction patterns. It also enables identification of cause–effect relationships in different teaching–learning scenarios, and allows for in-depth analyses of instructional processes.

In what follows, I will describe the type of data and data sources provided through the video design explored for the present study – the PISA+ Video Study.

1.2.1 Research Design and Data Sources

The PISA+ Video Study was designed to explore offered and experienced learning activities in the three PISA domains: science, mathematics, and reading (Klette 2009). Six grade nine classes (students aged 14—15 years) at six different schools were followed for 3 weeks in the subjects science, mathematics, and language arts. 45 science lessons, 37 mathematics lessons, and 44 language arts lessons were videotaped. In addition, video recordings from 10 cross-disciplinary lessons, plus video documentation of science excursions and experiments outside the classrooms were collected.

Pairs of students were interviewed (video-stimulated interviews) immediately after the lessons in science and mathematics. Teachers were interviewed once or twice during the three week observation period. Targeted interviews focusing on the students' reading habits and reading engagement were also conducted.

In summary, PISA+ contains video recordings from 140 videotaped lessons, 57 videotaped interviews with pairs of students ($n = 113$), 42 audiotaped student interviews (reading habits and reading engagement), and 18 interviews with teachers, plus copies of student work and assignments from the observation period. Table 1.1 gives an overview of the total data material.

1.2.2 Camera Set-Up

All lessons were filmed using three surveillance cameras; one remotely controlled following the teacher, one capturing the whole class, and one focusing on a small group of students, usually two (Fig. 1.1 gives an overview of the camera set-up). The small sized surveillance cameras that were used in PISA+ made the technology less intimidating. In order to reduce observer interference (Ericksson 2006; Klette 2009), the cameras were mounted before the lessons started and discretely placed.

Table 1.1 Overview of data material included in the PISA+ study

	Type of data source	Quantity	Type of data
1	Video recordings from science (n = 49), mathematics (n = 37), and language arts (n = 44) classrooms plus cross disciplinary lessons (n = 10)	$n = 140$	Coded video data
2	Video recording of pairs of students (number of students in total n = 113)	$n = 57$	Un-coded video data
2b	Transcriptions of videotaped student interviews	$n = 57$	Written transcriptions
3	Audio recordings from student interviews (reading habits and reading engagement)	$n = 42$	Written transcripts
4	Interviews with all videotaped teachers	$n = 18$	Written transcripts
5	Copies of lesson plans, work plans, student assignments and student work		Printed copies

Fig. 1.1 PISA+ video recording layout: three perspectives

The camera following the teacher was remotely controlled, while the two others were in stable positions. By using this camera set up, it was possible to back up the video documentation with participant observers being present in the lesson; one researcher following the group of students in order to prepare the interview and the other observing the whole class. The technology used also made it possible to conduct video-initiated interviews with students ($n = 113$) immediately after the lesson. Students watched sequences from the lesson and were asked to comment on their interpretation of the events. In this way, classroom observation data were compared to the students' interpretation of the events.

1.2.3 Sample: The Composition of Classrooms

The schools and classrooms in which the data were collected were chosen with the aim of providing as wide a span as possible across cases regarding student background and school organization. PISA has shown that achievement scores vary more within schools than between schools in Norway (Kjaernsli et al. 2004; Kjaernsli and Roe 2010). This means that students from one school may represent a broad range of knowledge and literacy skills. The schools in this study represent urban and rural areas, differences in socio-economic and ethnic backgrounds. They also represent a variation in terms of organization of lessons, that is, the use of architecture and physical space, lesson plans and time schedules, or the composition of the student groups.

1.2.4 Analyses

As indicated, one of the strengths of video data is how it may support analyses from multiple perspectives and involve either qualitative or quantitative inferences, or a combination of the two. The analyses that run through this book display and bring to the fore the various and differentiated modes of analyses that can be performed on video data, combining analyses of surface structures, such as instructional format and grouping of students, with micro-genetic analyses of teacher–student interaction and content coverage. Klette and Ødegaard (Chap. 2) combine, for example, systematic coding of instructional practices in science classrooms with in-depth analyses of the type of interaction that took place in the same classrooms. Bergem (Chap. 10) draws on video-stimulated interviews when disentangling different student strategies during independent work in mathematics. Anmarkrud (Chap. 3) combines analyses of teachers' reading instruction with teacher interviews in order to identify how, and to what extent, the students' experienced reading instruction in language arts. Roe, on the other hand (Chap. 6), draws on audiotaped interviews with 42 students on reading engagement to shed light on the same phenomenon. As yet another angle of analysis, Bergem (Chap. 4) combines data from the PISA+ mathematics classrooms with questionnaire data from PISA for Norway when discussing teacher support and student effort and perseverance in Norwegian secondary classrooms.

To construct profiles of the instructional choreographies and teacher–student interaction and student–student interaction across classrooms, each lesson was coded on different levels and conceptual scales using the software program Videograph.[1] Analyses have been conducted on several levels, discharging instructional format, instructional focus, and type of teacher-led activities across all the videotaped classrooms. For this purpose, we developed common coding manuals (see Klette et al. 2005). Targeted analyses of discourse features and interaction patterns linked to science (Ødegaard and Arnesen 2006) and mathematics (Ødegaard et al. 2007) classrooms have also been performed.

[1]Videograph is a computer software program developed at IPN, Kiel, http://www.ipn.uni-kiel.de/aktuell/videograph/htmStart.htm.

1.3 Research Contributions and the Composition of the Book

The proposed book draws on analysis that combines expertise in video-based microgenetic classroom studies with expertise in domain-specific instruction (math, science, and reading) and psychometrics. Whilst issues related to teaching, learning, and subject content are central to pedagogical practice, associated discussions tend to be fragmented. Despite a massive growth of studies of discourse patterns and dialogues in classrooms (Edvards and Mercer 1987; Wells 1999; Mortimer and Scott 2003; Alexander 2006), we still know little about the productive interplay *between* discursive engagements, instructional practices, and students' learning in different subject areas. Foregrounding interaction analyses (i.e., mundane talk and general linguistic maneuvers) and discourse analyses have contributed to expanding our understanding of the power of turn taking and competing voices in the classroom. How these discursive patterns interact with and support learning in different subject domains is, however, still an open question. And more importantly, how issues of communication patterns are dealt with and made productive within different instructional formats is still not in sight. This book feeds into such a discussion, and makes it possible to compare and analyze how instructional formats and discursive practices are made productive for students' learning.

The book is divided into three parts plus an Introduction. The first part – Instruction Matters – discusses instructional patterns within and across science, mathematics and language arts classrooms. The analyses indicate distinct differences between the three school subjects, with specific challenges and profiles within each subject (Chaps. 2, 3, 4, 5 and 6). While language arts classrooms, for example, seem to balance a certain variety of instructional practices, math classrooms suffer from monotony and repetitious ways of working, using either plenary teaching or individual seatwork as the basic form of instructional format.

The second part – Discourse Matters – analyzes language use and discourse features in the three subject areas (Chaps. 7, 8 and 9). Our analyses suggest that communication patterns in the observed classrooms are favorable for student initiatives and utterances. However, these utterances are for the most part concerned with practical and procedural questions, whereas substantive discussions linked to the subject area at stake are infrequent. We report, for example, on high student participation when it comes to turn taking and student–teacher interaction within both science and mathematics classrooms. However, how these interaction patterns contribute to students' learning within these two subject areas is unclear, and PISA and TIMSS data report average mathematics and science scores for Norwegian students at this level.

In the third part – Engagement Matters – we discuss how different instructional formats support student engagement with regards to the subjects at stake (Chaps. 10, 11 and 12). While student autonomy and student-centered ways of working have been actively promoted by educational policies, our analyses suggest that Norwegian students might have been left with too much responsibility for their own learning, with a lack of perseverance and determination as a consequence.

From different angles and data sources (video data, interviews with students, video-stimulated interviews, PISA and TIMSS questionnaire data), analyses from math and reading classrooms question the powerful balance between teacher–student engagement and teacher support.

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Part I
Instruction Matters

Chapter 2
Instructional Activities and Discourse Features in Science Classrooms: Teachers Talking and Students Listening or . . . ?

Kirsti Klette and Marianne Ødegaard

2.1 Objectives and Purposes

In this chapter we discuss the relation between instructional format and discursive patterns in science classrooms. While we acknowledge a huge body of research both within studies of instruction and discourse features in classrooms, related discussions tend to be fragmented. Despite a massive growth of studies of discourse patterns and dialogues in classrooms (Wells 1985; Edwards and Mercer 1987; Mortimer and Scott 2003; Alexander 2006) we still know, for example, little about the productive interplay *between* discursive engagements, instructional practices and students' learning in the different subject areas. Foregrounding interaction analyses (i.e. mundane talk and general linguistic maneuvers) discourse analyses have contributed to expand our understanding of the power of turn taking and competing voices in the classrooms. How these discursive patterns interact with and support learning in different subject domains are, however, still an open question and, more important, how issues of communication patterns are dealt with and made productive within different instructional formats is still not understood. In a recent large scale video study from the US, for example, no relationships were found between discourse features and student learning when examining whether different instructional patterns and discursive formats in mathematics and English Language Arts had an impact on students' achievement scores (Kane et al. 2011). To maximise their impact, we will argue in this contribution, analyses of classroom dialogues must be brought together with analyses of instructional patterns and linked to specific content areas. For this purpose, in this chapter we bring together

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studies of discourse features and research on instructional format when analysing offered and experienced learning in science classrooms.

Scholars around the world have come to agree on the crucial role dialogues and classroom discourse play for students' learning (Alexander 2006; Dysthe 1995; Edwards and Mercer 1987; Littleton and Mercer 2013; Lemke 1990). Significant work has been conducted on the ways in which classroom communication, and particularly classroom talk, can be used to support science learning and scientific understanding (Erudan et al. 2004; Lemke 1990; Mortimer and Scott 2003; Ogborn et al. 1996).

From another body of research we know that teaching and learning in science classrooms paraphrase a very stable and well known pattern of classroom interaction and teaching format (Cuban 1993; Driver 1983; Goodlad 1984; Jorde 1986; Lemke 1990; Mehan 1979; Mortimer and Scott 2003; Stigler and Hiebert 1999). In these studies science education is portrayed as a mixture of teacher-led whole class instruction and plenary talk, individual seatwork and laboratory work, and students are left with few opportunities to raise their voices and 'talk science' (Lemke 1990). However, recent classroom studies (Klette 2004; 2009; Ødegaard and Arnesen 2010; Clarke 2006; Coburn 2004; Emanuelsson and Sahlström 2006; Lindblad and Sahlström 1999) seriously question and dispute conventional knowledge about classroom teaching and interaction as depicted in earlier studies. Emergent studies from Nordic classrooms (Emanuelsson and Sahlström 2006, 2008; Ødegaard and Arnesen 2010; Klette 2009) indicate, for example, how the prevalence of whole class instruction is combined with an altered student–teacher relation in Swedish and Norwegian math and science classrooms. Analyses of communication patterns in these classrooms (Aukrust 2003; Emanuelsson and Sahlström 2008; Bergem and Klette 2010) suggest extended opportunities for students' initiative and student engagement.

In this chapter we will use video data to discuss the interplay between instructional practices and discursive patterns in lower secondary science classrooms. New technologies and research design, such as video documentation, makes it possible to simultaneously record both student and teacher interactions, and enables researchers to work with interaction patterns and instructional formats simultaneously. Video documentation makes it possible to record, analyze and combine different 'texts at play' (Sherin 2004) and as such enlarge our understanding of what goes on in classrooms. Such 'texts' could be student–teacher interaction, student–student interaction, teachers' instructional repertoires, and types of dialogues including the content//subject matter involved. Thus, video documentation makes it possible to link instructional patterns with discursive features of teacher–student interaction, and initiation patterns within a coherent framework.

We start out by summarising relevant literature on instructional formats and classroom discourse in science classrooms. We then present data and methods for the inquiries, and finally we turn to the presentation of the analyses.

2.2 Instructional Format in Science Classrooms

Several studies (Cuban 1993; Jorde 1986; Lemke 1990; Mortimer and Scott 2003; Nystrand 1997) document the pervasiveness of plenary teaching where whole class instruction combined with individual seatwork and group work/laboratory work are predominant in science classrooms. The concept of whole class instruction as plenary teaching is, however, not very clear-cut or defined concept and can convey rather different instructional approaches. Nystrand (1997) distinguishes, for example, between recitation, dialogic instruction and discussion as three features of teacher-led whole class instruction. Klette and colleagues (2005) define monologic instruction (lecturing), dialogic instruction, question/answer sequences and whole class discussion as four different features of teacher-led whole class instruction. In this chapter we argue that by separating the concept of teacher-led whole class instruction into more specific and distinct subcategories, such as the distinction between monologic instruction (i.e. lecturing, recitation) and dialogic instruction, we are able to explore the possible developments and dynamics of interaction between teachers and students within the rather broad category of 'teacher-led whole class instruction'. Klette (2010) and Popkewitz (2000) argue that many studies continue to use rather general and dichotomized conceptual language – what Clark among others labels 'false dichotomies' (Clarke 2006) – when analysing instructional formats in science classrooms and consequently end up paraphrasing the status quo. The dichotomized conceptual language available (e.g. monologue versus dialogue; talking versus listening; teacher centered versus student centered) tends to force analysts to label the activity as *either* teacher-led instruction *or* student participation, with little latitude for transcending and blurring descriptions. If we divide whole class instruction into subcategories such as lecturing, dialogic instruction, 'going over the do now', classroom dialogue and question/answer sequences, all possible categories for teachers' instructional format during whole class instruction, we might get a more nuanced, updated and accurate picture of what constitutes whole class instruction in today's classrooms. As early as 1969 Barnes and his colleagues showed, for example, (Barnes et al. 1969) that science lessons gave more space and place for student-initiated questions than was recognized in other lessons and subjects. Emanuelsson and Sahlström (2008) and Klette and colleagues (Klette 2003; Klette et al. 2008) show how whole class instruction still dominates science and math classrooms in, respectively, Sweden and Norway. But they also show how whole class instruction today involves extended possibilities for student initiatives and student responses compared to the instruction portrayed in earlier studies.

2.3 Classroom Discourse

A large volume of research underscores how learning is linked to meaning-making and language use across contexts (Alexander 2000, 2006; Mortimer and Scott 2003; Vygotsky 1978). Understanding dialogues and classroom discourse is consequently of uttermost importance if we want to understand and improve learning in science classrooms. Wellington and Osborne (2001) classify research on classroom dialogue and show how the general dilemma of teaching science as an accepted body of knowledge and at the same time as a process of genuine enquiry, in which students should generate their own understanding of events and phenomenon, may influence and produce conflicts in different areas of science teaching. This dilemma is apparent, for instance, in the art of questioning. It is not unusual to observe teachers asking what seems like an open-ended question, but only acknowledging one answer as correct, a so-called 'pseudo-question' (Barnes et al. 1969). Several studies document the pervasiveness of these 'pseudo-questions' (Edwards and Mercer 1987; Mortimer and Scott 2003; Wells 1985). Another well-documented feature of classroom discourse is the predominance of teachers talk and the repeated 'IRF' pattern. The dominant pattern of interaction follows a predefined IRF (E) pattern of communication (Cazden 2001; Dysthe 1995; Edwards and Mercer 1987; Lemke 1990; Mortimer and Scott 2003) where the teacher poses a questions or initiative (I) followed by a student's response (R) which is then followed up (F) or evaluated (E) by the teacher. According to this research, the pupils are left with small possibilities for participation and influence within these patterns of communication. Several studies document the prevalence of these communicative patterns of interaction in classroom discourse. In a more recent study Juzwik and colleagues (2008) underscore, however, the dynamic exchange mechanisms between monologic and dialogic instructional formats. They show how monologic instruction formats might change to dialogic formats as the teachers opens the floor to student initiatives and competing ideas and voices (ibid, p. 1115). Furtak and Shavelson (2009, p. 201) show how a balanced mixture of authoritative and dialogic teacher-led questions are productive for students' science learning. Most productive for students learning were units with varied teacher guidance within and between discussion segments, and where teachers used their authority in leading the whole class discussion to address concepts (p. 200).

As indicated above, Barnes and colleagues had already recognised a certain space for student-initiated questions in science classrooms by the late 1960s. Interestingly, in their work, Barnes et al. show how approximately one-third of the questions in science are open-ended, and that, compared to other subjects, science is the subject in which students asked most reasoning questions and fewest factual questions (Barnes et al. 1969; Barnes 2008) . While investigating why students do not actively ask many questions of their teacher, Barnes found that in 'pupil-initiated sequences', the most frequent kind of question was about the method of carrying out a task: "What kind of pencil should we use?". The very few other examples were requests for information, for information to confirm an insight and for a theoretical explanation, and general statements made by the pupils (Barnes et al. 1969). In

Norwegian secondary classrooms, Klette (2003) and Aukrust (2003) report a social climate favourable to student-initiated questions. These questions are, however, to a large extent procedural and practical (Ødegaard and Klette 2012), and situations where the student use questions to thematically explore a field of knowledge are rare.

2.3.1 Language in Science Classrooms

As emphasised above, the use of language in a social context is of crucial importance for science education. Learning science is learning to talk science, not only understanding science concepts but also learning to use structures and features of the scientific language. Mortimer and Scott (2003) emphasise language as a fundamental tool for learning, and, like Bakthin (1953/1980), Wertsch (1991) and others, they recognize different discipline-based social languages which can be seen as toolkits for talking and knowing. Mortimer and Scott (ibid.) use the distinction between an ‘everyday’ social language and a scientific social language based on Vygotsky’s everyday and scientific concepts (Vygotsky 1978) when they study language practices in science classrooms. They also focus on three fundamental features of the scientific social language: description (an account of a system, object or phenomenon), explanation (importing some form of a model or mechanism to account for a specific phenomenon) and generalization (a description or explanation that is independent of any specific context).

What are the roles of everyday explanations versus descriptions in our classrooms? Are the students given possibilities to engage in everyday language practices and scientific language practices? And, overall, how does the instructional format provide opportunities for student engagement and the possibility to ‘talk science’? Before we answer these general and specific questions we briefly describe our methods, modes of inquiry and data sources.

2.4 Methods, Modes of Inquiry and Data Sources

In order to get a fuller understanding of the interplay between instructional and discursive patterns in science classrooms, we deployed coding schemes operating on different levels and with different analytical perspectives. Theories of classroom teaching and instruction (Cuban 1993; Driver 1983; Klette 2003; Nystrand 1997) were used to develop categories to depict instructional formats across sites and classrooms. Theories of socio-cultural learning in combination with Vygotskyan inspired theories of language (Lemke 1990; Mortimer and Scott 2003) were applied for capturing classroom discourse and features of language. Rather than seeing these theories as competing analytical perspectives, we saw them as compatible dimensions of classroom teaching that should be brought together for the sake of understanding learning in science classrooms.

Table 2.1 The sub-codes for the element instructional format in the coding scheme (Klette et al. 2005)

	Code	Explanation
1	Whole-class instruction	Teacher lectures/organize learning activities for the whole class
2	Individual seat work	Student works individually with assignments, etc.
3	Group work	Student work in group/or pair as a part of their assigned work

Table 2.2 The sub-codes for the element "Whole Class Instruction" within the coding scheme instructional format (Klette et al. 2005)

Code	Explanation
1. Whole class Instruction: monologue	Teacher lectures the whole class. Teachers lectures uninterrupted minimum for 3-min when this code is used
2. Whole class Instruction: dialogue	Teacher lectures the whole class. The teacher allows for questions/comments from the students, and also ask questions to the students
3. Question/answer sequnces	Teacher uses questions to check out students' knowledge and insight
4. Discussion	Dialogue pattern in which students speak directly/comment on one another about the subject matter/teacher acts as moderator
5. Student presentations	Students present assignments, dramatization, projects, etc.
6. Task management	Teacher gives verbal/non-verbal instructions regarding assignments and class projects (grouping, material resources i.e)
7. Comments on misbehavior	Teacher deals with student misbehavior (This code can be combined with category 2,3, 4, 5 & 6)
8. Practical messages	Teacher gives non-academic information (about parental meetings, school trips, and student duties) (This code can be combined with category 2,3, 4, 5 & 6)

The coding schemes differed in focus and grain size. Coding scheme 1 (Klette et al. 2005) mapped instructional formats such as whole class instruction, group work/laboratory work individual seatwork, and physical grouping of the students. Whole class instruction was divided into subcategories such as monologic instruction (teacher lecturing more than 3 min without students interrupting), dialogic instruction, question/answer sequences, whole class discussion etc. For description of the subcategories within the main categories of instructional format – see Tables 2.1 and 2.2. Coding Scheme 2 (Arnesen and Ødegaard 2006) had features of language and discourse between teachers and students during whole class instruction as its focal point. Here we mapped features of social language (everyday, scientific), features of scientific discourse (descriptions, explanations and generalizations) and initiation patterns. The distinction between teacher-initiated dialogues, student-initiated dialogues and teacher exposition defined how we charted coding procedures, for example, initiation patterns. For a description of the subcategories used in this analysis, see Table 2.3 below.

To make profiles and patterns across classrooms, each lesson has been analyzed quantitatively using the software tool Videograph (Rimmele 2002). With Videograph it was possible to view the digital video data (covering three cameras)

Table 2.3 The sub codes for analysing discourse features (initiation patterns and social language) in science classrooms (see Ødegaard and Arnesen 2006)

Code/subcodes	Description of the subcode
Initiation patterns	
Student initiative	A student makes a comment or asks a question that brings up a new theme or issue. Includes also the answer or comments from teacher or students
Teacher initiative	Teacher asks questions in order to use or mobilize students' knowledge when developing new knowledge. Includes also the answer or comments from students
Teacher lecturing	Teacher presents or explains something by talking without including students
Social language	
Everyday language	Teacher and students use everyday concepts and language
Scientific language	Teacher and students use scientific concepts and language

synchronized to a coding scheme containing relevant coding categories as tools for studying the observed lessons.

We used the physical timeline and coded second per second for each lesson. For the purpose of statistical analyses, the individual timelines from each lesson were combined to identify the frequency of each activity code. The quality of the coding procedures is reliant on the size of the data material and the people who actually performed the coding. All common coding procedures were therefore reliability tested; and the inter-rate reliability scores were satisfactory (80–90 %). For one of the sub-codes in the instructional pattern coding scheme the inter-rate reliability was around 70 %, and therefore the two codes 'question/answer' and 'dialogic instruction' were combined in a joint code for future analyses.

2.4.1 Data Sources

The analyses draw on video recordings of 45 science lessons from ninth grade classrooms (students aged 14–15 years) from six schools. The schools were chosen to provide a wide span of student background and school organization. The schools in this study represent urban and rural areas, differences in socio-economic and ethnic backgrounds, and traditionally and alternatively organized schools. Each school was followed for 2–3 weeks. All lessons were filmed using three surveillance cameras; one remote controlled following the teacher, one capturing the whole class and one focusing on a small group of students, usually two. The use of surveillance cameras made the technology less intimidating. For more details about the methodological design and set up for the whole study, see Klette (2009).

2.5 Findings: Instructional Patterns and Discourse Features in Science Classrooms

2.5.1 Instructional Repertoires

Our analyses indicate that, at first glance, observed instructional repertoires in science classrooms support and confirm existing research from science classrooms in terms of the prevalence of teacher-led plenary instruction. Based on prevailing conceptual categories such as whole class instruction, group work/laboratory work, and individual seatwork, our data paraphrase a very well documented pattern of science education of basically teacher-led teaching. (See Fig. 2.1, below.) Due to constraints in our research design (e.g. whole day excursions that could not be filmed) the amount of group work, which includes exercises and laboratory work, can be slightly adjusted, but even so science has a distinct profile of teacher-led instruction. So at this stage one might conclude that science teaching is practised in quite a traditional way with the teacher lecturing and the students mainly taking notes and listening.

However, if we divide the category of teacher-led instruction into sub-categories, and distinguish between monologic instruction, dialogic instruction, whole class discussion, question/answer sequences etc. (e.g. Table 2.2 above), we see that, for instance, teacher monologues (defined as teacher lecturing for at least 3 min without any students interrupting) are almost non-existant in the videotaped classrooms (see Fig. 2.2 below). What characterises the teaching practices in these classrooms is what we have termed dialogic instruction where students play an active part in terms of posing questions and making statements. Whether this represents extended opportunities for meaning making and talking science, as outlined by Lemke (1990),

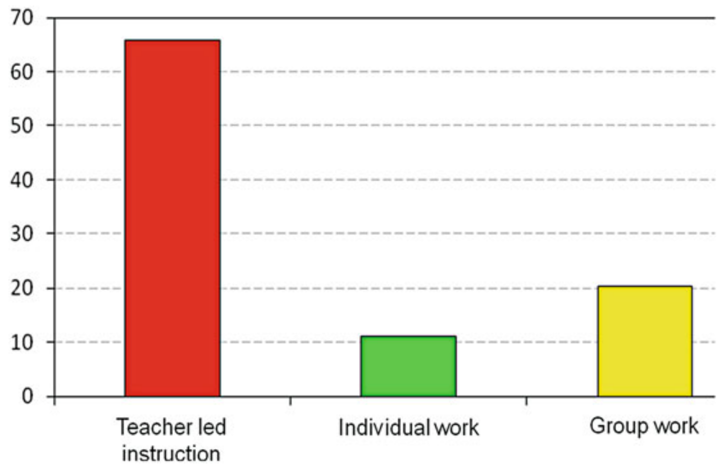

Fig. 2.1 Instructional format as a percentage of filmed time in six science classrooms

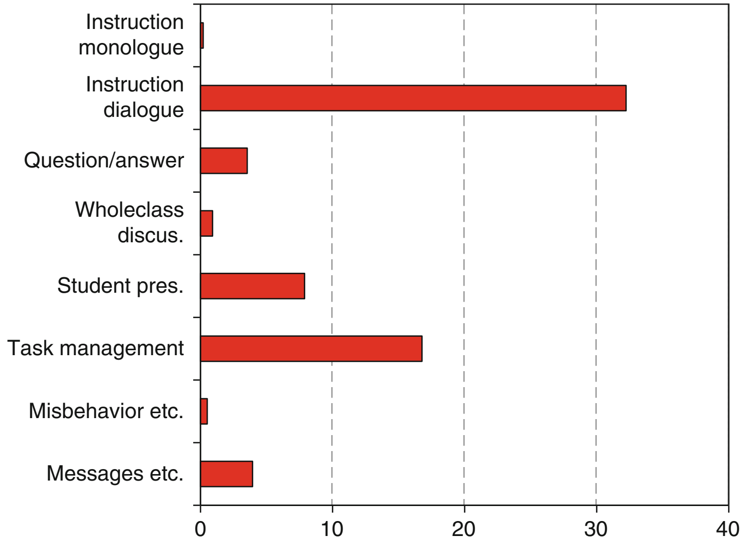

Fig. 2.2 Features of whole class instruction as a percentage of filmed time in our science classrooms

Mercer and Hodginson (2008), Wellington and Osborne (2001) and others, is however an open question. This will be further investigated with the next coding scheme where we use features of dialogues and language as analytical lenses.

Another noteworthy feature of teacher-led teaching in the observed science classrooms is the role of task management. Task management in our coding manual was defined as 'teacher giving instructions about required student activities, assignments etc'. In science this might mean giving instructions about practical work, seatwork, or organising group work and excursions etc.

At this point, we might conclude that teacher-led *dialogic* instruction predominates in the observed science classrooms, which indicates/suggests space for student initiatives and possible student involvement.

2.5.2 Discourse Features and Initiation Patterns

The second analysis scheme focused on social language and discourse features (e.g. initiation patterns). In our coding categories of classroom dialogue (Arnesen and Ødegaard 2006) we have coded for both teacher and student initiatives, defined as a sequence of questions, answers or comments that is initiated by either the teacher *or* the student. A third code is labelled 'teacher lecturing', which indicates teacher talk without interruption. Unlike 'teacher monologue' in Coding Scheme 1, this does not have to be 3 min or more. For features of language we distinguished between

Fig. 2.3 Classroom dialogue in during teacher-led instruction as a percentage of videotaped science lessons

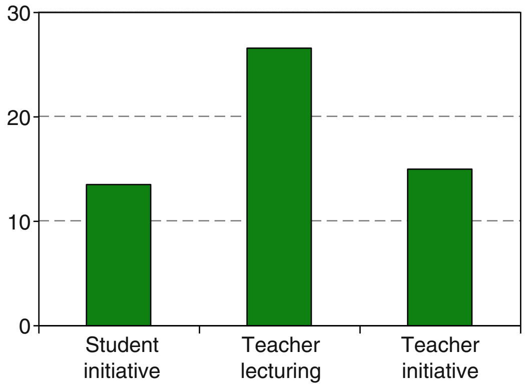

Table 2.4 Student initiatives with examples from one lesson

Student initiatives from one lesson ($n = 26$)	Occurrences
About blackboard//taking notes: "Should we write it in our book?"	9
About practical//organization: "Who is in that group?"	7
About practical work: "What are we supposed to do?"	3
Comments to science issues: "Shouldn't it be hydrogen, not nitrogen?"	5
Own meaning making: "Is this about photosynthesis?"	2

whether the social language used in the classroom discourse could be labelled 'everyday' language//or scientific language.

Based on the initiator of the utterances, in our data students and teachers show nearly equal opportunities for *initiating* classroom talk. Teachers still dominate classroom talk in terms of time spent on talking, but with a more mixed communicative pattern which includes more student initiatives than documented in earlier studies. From Fig. 2.3 we see that student initiatives are almost as frequent as teacher initiatives. Thus, our second analytical approach, which focuses on *who* initiates the conversations in class, enriches the general impression of the flow of talk in our science classrooms. This shows that on a procedural level (e.g. who initiated the dialogue) the classroom discourse is student inclusive and gives a certain amount of room for student initiatives.

Further inquiry into the quality and impact of student initiatives at a micro-level is required in order to reveal the consequences of this emerging pattern. On narrowing down our investigation to substantial in-depth analyses of the student initiations, we find like Barnes (Barnes et al. 1969; Barnes 2008) that the student-initiated sequences are mainly questions about ways of carrying out a task. Table 2.4 below illustrates an in-depth analysis of one lesson. The lesson analysed was a quite structured science lesson about photosynthesis, with both theory and practical work. As indicated in the table, of 26 student initiatives, only seven were directly related to science issues. Although this is only one example of a lesson, the ratio of science-related talk (less than one-third) is confirmed by cross-table analyses between student initiative and features of scientific talk (see Ødegaard and Arnesen 2010).

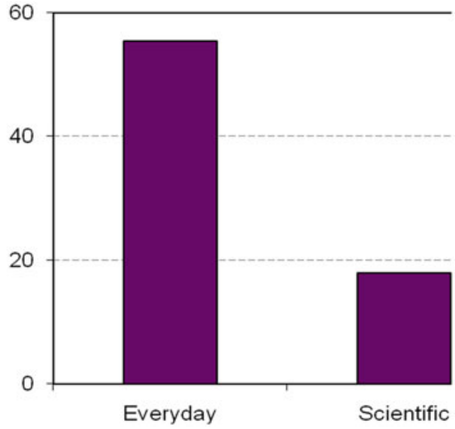

Fig. 2.4 Social language in classroom dialogue following the teacher, as a percentage of videotaped science lessons

More in-depth research on these situations will give us further information about the significance of these patterns of initiative. For instance, how does the teacher respond to the different student initiatives? How much science is brought in to task management issues? At this point the overall picture puts emphasis on the procedural and task-related enquiries regarding student-initiated questions.

Another analytical approach for digging in to the complexity of interactions in science classrooms in Coding Scheme 2, is examining features of language. One of the categories we used for analysis is social language, which tried to capture whether the social language used in the classroom discourse is of an 'everyday' or scientific nature. Scientific language is defined as the use of scientific concepts (Mortimer and Scott 2003), and is coded by following the teachers' conversation with the students and includes both teacher and student talk. Our analyses show that scientific language is used in only a small part of a whole lesson. Less than 20 % of coded time in our science lessons is labelled scientific language (see Fig. 2.4).

However, we found that categorising language as 'everyday' or 'scientific' is problematic. We see that merely using scientific concepts in classroom talk is not a meaningful and precise definition for scientific language. In-depth analysis of sequences labelled as everyday language in our coding might illustrate this important point. It is not just the amount of time the students are exposed to scientific concepts that needs to be considered, the content and thematic quality of the talk must also be scrutinized. This is illustrated by the following example, which is a small excerpt of a teacher–student dialogue from a photosynthesis lesson from School 3:

T: Have you seen what comes up from the ground, the first that comes up from the ground?
S: One of those little green things.
T: Yes. Have you noticed how many leaves there are on it?
S: Two
T: Yes, good. Excellent.

Both the teacher and the student use everyday language in describing a scientific phenomena, which is labelled ‘little green thing’ by the student. This label is not changed to a more scientific concept by the teacher throughout this sequence, and thus the label ‘little green thing’ can continue to be used by the students. However, according to Lemke, this small dialogue is part of a scientific thematic pattern; ‘the little green thing’ is given a descriptive characteristic: *green* and it is classified as having two leaves. And further into the dialogue, the teacher classifies the ‘the little green thing’ as a dicot. In his semiotic analyses, Lemke (1990) refers to this as a nominal and a taxonomic relation. When thematic patterns are repeated they give an implicit message to the students of how science is organised. Thus, after many examples of describing and classifying organisms, in science lessons and in science text books, students will recognise this as one of the patterns of talking science. What is lacking, however, is a more explicit and teacher-driven vocabulary that is able to link concepts like ‘the little green thing’ to relevant scientific concepts such as ‘germ’ or ‘seedling’.

2.6 Discussion

Contrary to the conclusions from earlier studies, our analysis suggests that teacher-led instruction in the observed classrooms is more dialogic and less authoritarian – and teacher centred – than indicated in these previous studies. Fine-grained analyses of instructional repertoires during whole class instruction and examinations of actors’ initiatives indicate a more active and autonomous student role than depicted in earlier studies, even though the initial analyses, based on established conceptual categories for measuring teaching practices, seemed to support and confirm existing research from science classrooms in terms of the prevalence of teacher-led plenary instruction.

By narrowing down the analytic focus using actors and dialogue features, initiatives and social language as units of analyses these findings were further scrutinized. Based on the initiator of the utterances, students and teachers show nearly equal opportunities for *initiating* classroom talk. Teachers still dominate classroom talk in terms of time spent on talking, but with a more mixed communicative pattern which includes more student initiatives than documented in earlier studies. However, our analyses of student-initiated sequences so far reveal (like Barnes et al. 1969) that these questions are mainly concerned with practical matters and ways of carrying out a task. The proportion of science-related talk in student-directed initiatives was less than 30 % (Ødegaard et al., See Chap. 7). Analyses of social language in classroom dialogue (e.g. everyday language and scientific language) support this finding.

Taken together, these aspects of classroom learning – instructional format, classroom discourse and features of language used in science classrooms – establish a mixture of well-known and new ingredients. Depending on thematic approach, analytical categories and grain size of analyses, stable and emerging patterns of teacher–student interaction can be exposed. How student initiatives as communicative patterns have impact on the scientific *thematic patterns*, and also on students' learning needs, however, further investigation.

2.7 Conclusion

In this chapter we have discussed the productive interplay of bringing together different conceptual approaches in order to understand classroom learning. Research on classroom learning has been suffering from dichotomized conceptual language, and what Clarke (2006) and others describe as 'false dichotomies' with few layered and nuanced/multifaceted descriptions.

By combining analytical categories from research on teaching and instructional format with categories analysing classroom discourse we show how instructional practices of today on the one hand provide opportunities for student engagement and student initiatives. Fine-grained analyses of these initiatives reveal, on the other hand, that almost 70 % of these initiatives are what we describe as procedural and are not substantial or linked to science education. Teachers' careful and explicit framing and focus on conceptual understanding could be one way to convert these patterns of participation into patterns of clarification.

There are many ways to conceptualize classroom teaching and learning. In this chapter, we have explored the insights offered by applying two rather different approaches to studies of teaching and learning in science classrooms, e.g. discourse features and instructional format and linking it to in-depth studies of teaching/learning activities in science classrooms. This strategy of using parallel analyses of a common data set to generate 'complementary accounts' (Clarke 2001) has become one of the benefits and key characteristics of video studies (Clarke et al. 2006; Klette 2009; Fischer and Neumann 2012). Such an approach is nurtured by a belief that no single analytical perspective can capture the complexity of a classroom, and that the information offered by differently situated analyses is more than the sum of the separate analyses, since the comparison facilitates the identification of commonalities in findings. Comparison also reveals differences in account, which help to identify situations and events open to multiple explanations, offering alternatives, prompting further questions, and thus suggesting avenues for further research.

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Chapter 3
Inquisitor, Evaluator or Facilitator?

Teachers' Use of Instructional Format During Naturally Occurring Comprehension Strategies Instruction

Øistein Anmarkrud

Comprehension instruction, or the lack of it, has been given considerable attention by reading researchers, policy makers, and teacher educators during the last 30 years (Pearson 2009). Researchers have made significant progress in identifying and addressing several important components and processes involved in skilled text comprehension, with active and flexible strategic processing described as a hallmark of expert reading within an academic domain (Pressley and Afflerbach 1995; Strømsø et al. 2003). Thus, a substantial amount of research effort has been put into instructional research, making it possible to give research-based recommendations on what comprehension instruction should look like in the classroom (Dewitz et al. 2009). Because the majority of the instructional research is conducted in elementary and middle-grade classrooms, less is known about comprehension instruction, particularly about instruction in comprehension strategies, as it is regularly offered adolescents in secondary schools (Conley 2009).

In a majority of the published instructional research, collaborative learning has been regarded as a crucial vehicle in the fostering of strategic and engaged readers. The main purpose of this chapter is to provide a detailed description of how teachers use instructional formats in their naturally occurring comprehension strategies instruction, and particularly if, and how, they facilitate collaborative learning of strategic reading.

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3.1 Strategic Reading

Building on the conceptualizations of strategies presented by Weinstein and Mayer (1986) and Alexander et al. (1998), comprehension strategies can be defined as forms of procedural knowledge that readers voluntarily use to acquire, organize, and transform information, as well as to reflect on and guide their own text comprehension. Because readers are assumed to use strategies in order to reduce a perceived discrepancy between a desired outcome and their current state of understanding, comprehension strategies are also conceived of as deliberate and goal-oriented processes used to extract and construct meaning from text (Pressley and Hilden 2006).

A large number of comprehension strategies are described in the literature. Thus, Pressley and Afflerbach (1995) identified more than 100 different strategies in their review of think-aloud studies. As argued by Strømsø et al. (2003), these strategies may be captured by the broader categories of memorization, organization, elaboration, and monitoring, which figure in Weinstein and Mayer's (1986) taxonomy of general learning strategies. In the domain of reading comprehension, memorization strategies are used to select and rehearse information, without transforming or moving beyond what is given in the text itself (e.g., highlighting or repeating sentences to select and remember them). Organization strategies are used to relate, group, or order information and ideas given in the text (e.g., summarizing, outlining, or diagramming text information). Elaboration strategies are used to make content more meaningful by building connections between information given in the text and information located in other sources (e.g., associating with relevant prior knowledge or linking content to the content of other available reading material). Finally, monitoring strategies involve readers assessing or regulating their comprehension (e.g., comprehension confirmation, problem detection, and problem solving).

3.2 Instructional Research

Durkin's (1978/79) landmark classroom study of comprehension instruction in fourth-grade classrooms, revealing that teachers spent virtually no instructional time improving students' text comprehension, was a catalyst for a more focused research agenda on comprehension instruction, including both experimental intervention research and descriptive classroom studies (Block and Duffy 2008). In the next sections, I review both lines of research with a focus on comprehension strategies instruction. It should be noted, however, that, thus far, instructional research focusing on comprehension strategies has mainly been conducted in elementary- and middle-school classrooms, and strategies instruction while adolescents read expository texts to learn academic content is seldom addressed (Conley 2009).

3.2.1 Experimental Work

A substantial amount of effort has been invested in experimental work examining if and how students can be taught to read more strategically and expertly (Pressley 2006). That research (cf. Brown et al. 1996; Guthrie et al. 2007; Palincsar and Brown 1984) has come a long way in identifying the ingredients of efficient comprehension strategies instruction. Five such ingredients are briefly summarized below.

First, strategies need to be directly and explicitly taught. Although some students may seem to learn strategies without direct instruction, few researchers would question the importance of direct and explicit instruction (Block and Duffy 2008). Modeling, verbalizing, and scaffolding strategy use have thus been important parts of most comprehension strategy interventions since the early studies of direct instruction in the 1980s (cf. Bereiter and Bird 1985; Duffy et al. 1987). The progression from teacher or peer modeling to guided practice and, finally, students' independent application of strategies is thus integrated into several recognized interventions, such as Transactional Strategy Instruction (Brown et al. 1996; Pressley et al. 1992) and Concept-Oriented Reading Instruction (Guthrie et al. 1996, 2004).

Second, to ensure flexibility, efficient comprehension instruction includes instruction in multiple strategies to establish a repertoire of (usually four to six) deeper-level strategies that can be adapted to particular texts and tasks. Deeper-level comprehension strategies are presumably required to construct mental representations that reflect deep, inferential understanding of text content (Graesser 2007; Magliano et al. 2007).

Third, the idea of reading comprehension as a collaborative social activity is permeating most contemporary strategy interventions (Dole et al. 2009). On the one hand, collaborative comprehension may refer to groups of students who join forces in text-based meaning making, on the other to high-quality dialogic discussions about text and text content taking place in the whole class (Almasi and Garas-York 2009). In contrast, teacher-led discussions often take the form of IRE (initiation–response–evaluation) sequences, where teachers initiate a discussion, typically by asking a question, students respond, and teachers evaluate their responses (Cazden 1988). Whereas more open dialogic approaches to classroom discourse have been found to support student engagement and text comprehension (Applebee et al. 2003), IRE sequences are more likely contribute to passivity, decreased motivation, and reduced cognitive engagement (Almasi and Garas-York 2009). Collaboration in reading groups may thus be supplemented with open whole class dialogues about text content (Gaskins et al. 1993; Guthrie and Davis 2003; Pressley et al. 1992).

Fourth, the development of strategic reading requires quite some time. This is reflected in the extent of effective interventions, lasting from 12 weeks (cf. Guthrie et al. 2004, 2006; Wigfield et al. 2004) to an entire school year (cf. Brown et al. 1996; Guthrie et al. 2000), with long-term instruction of deeper-level strategies preferably also integrated into subject-matter learning.

Fifth, an important ingredient of efficient comprehension strategies instruction is professional development for teachers (Block and Duffy 2008). In CORI (concept-oriented reading instruction; Guthrie et al. 2004), for example, participating teachers receive up to 10 days of professional development courses to prepare them for high-quality comprehension instruction. Such preparation seems necessary because several studies indicate that teachers often base their classroom practice on personal experience rather than research-based knowledge (Grimmett and Mackinnon 1992; Klette and Carlsten 2012), a finding also reported with respect to reading instruction (National Reading Panel 2000; Pressley et al. 1998; RAND Reading Study Group 2002). Even with considerable professional support, however, teachers may find it difficult to gain sufficient knowledge to provide efficient instruction in strategic reading (Hilden and Pressley 2007).

In summary, then, the intervention work indicates that efficient comprehension strategies instruction requires that schooled teachers directly and explicitly teach a repertoire of deeper-level comprehension strategies over time, with such strategies practiced and used by students to collaboratively construct meaning from texts during subject-matter learning.

3.2.2 Descriptive Work

Descriptive studies of naturally occurring comprehension instruction represent another line of research on comprehension strategies instruction. In this work, one important research agenda is to explore to what extent insights gained from intervention studies are reflected in the day-to-day reading instruction that can be observed in classrooms (Pressley 2009). However, this research has, to the best of my knowledge, been limited to observations conducted in North American elementary- and middle-grade classrooms.

For example, Pressley et al. (1998), who observed literacy instruction in 10 fourth- and fifth-grade classrooms, found that direct and explicit instruction in comprehension strategies was virtually non-existent. The teachers, all considered to be excellent reading educators, occasionally mentioned a comprehension strategy (e.g., predicting, summarizing), and sometimes modeled the use of strategies, "but there was no evidence that teachers instructed or encouraged students to coordinate the various comprehension strategies in order to understand text" (p. 172). With respect to instructional grouping during reading instruction, the classrooms were reported to differ. In many of the classrooms, teacher-led whole class instruction was predominant, particularly in the form of class discussions driven by teacher questioning, but small group reading instruction was also a salient feature in many of the classrooms. The researchers did also observe teachers engaged in one-on-one mini-conferences with students during reading instruction. Although there were differences between the participating teachers with respect to instructional grouping during reading instruction, it seemed reasonable to characterize the reading instruction as diverse in instructional format. Interviews with the participating teachers revealed that the use of instructional formats in reading instruction was deliberate and tied to tasks and texts.

The 12 fourth-grade teachers participating in Allington and Johnston's (2002) in-depth classroom study were also considered to be exemplary reading educators. In these classrooms, all teachers commonly encouraged students to use text-to-text connections, and some teachers also encouraged students to make text-to-self and text-to-world connections. According to Allington and Johnston, reading was indeed a collaborative activity in the classrooms they observed. Collaborative, meaningful problem-solving was common, and the students in these classrooms learned how to learn from each other, teach each other, and interact with each other in ways that promoted mutual learning. Due to this, teachers expected students to display good collaborative skills, and collaborative breakdown during collective learning was not treated as misbehavior, but as an interactional problem that should be dealt with strategically. Whole class instruction was an instructional format observed with low frequency. When this instructional format was observed, it was primary as whole class discussions of high quality, where tentative talk and students commenting on the contributions from their classmates was a prominent feature of the discussions.

In a more recent study, Pressley et al. (2007) observed reading instruction at Bennet Woods, an elementary school recognized for high-quality reading instruction. Compared with the Pressley et al. (1998) and Allington and Johnston (2002) studies, explicit instruction in comprehension strategies appeared to be a frequent activity at this school. Pressley et al. (2007) do not report details concerning teachers' use of instructional format during strategies instruction, but report that students were participating in partly student-driven, mature and dialogic discourses during both whole class and group-based strategies instruction. However, more traditional teacher-driven question–answer sequences following the IRE pattern (Cazden 1988) were also observed.

3.3 Comprehension Strategies Instruction in Norwegian Ninth-Grade Classrooms: Amount and Instructional Format

In the PISA+ project, teachers' use of instructional format during naturally occurring comprehension strategies instruction was examined in four language arts classrooms. In all four classrooms, expository texts were the main topic during the observational period.

3.3.1 Participants and Analysis

Hannah was 59 years old and had been a full time teacher for 25 years. She was teaching at a small school located in a rural area. There were 32 students in her class (17 boys, 15 girls). According to Hannah, the majority of her students were reading at ninth-grade level, with five or six students characterized as really good readers and just a few as struggling readers.

Leila was 49 years old and had been a full-time teacher for 24 years. She was teaching in a large suburban school. There were 25 students in her class (12 boys, 13 girls). Two of the students received special needs education. According to Leila, 10 of her students were really good readers, a few were average, and the rest had "quite a way to go".

Nina was 30 years old and had been a full-time teacher for 5 years. She was teaching in a large suburban school. There were 26 students in her class (12 boys, 14 girls). According to Nina, the majority of her students were relatively strong readers, with only a couple of students in need of some extra attention in regard to reading.

Finally, Monica was 42 years old and had been a full-time teacher for 12 years. She was teaching in large urban school. There were 28 students in her class (15 boys, 13 girls), including 18 language minority children. Three students received special needs education. According to Monica, most of her students had average reading skills, and there were few really good or struggling readers in her class.

Four lessons were randomly drawn from each of the four classrooms. The 16 lessons were then coded with two different coding schemes. The first coding scheme, developed collaboratively by the PISA+ group, examined the teachers' use of different instructional formats in their reading instruction. This coding scheme consisted of three main categories: whole class instruction, individual seatwork, and group work. Each of the three main categories included several subcategories.

Next, all lessons were coded with a coding scheme developed to capture the teachers' instruction in comprehension strategies. This second scheme was based on Weinstein and Mayer's (1986) strategy taxonomy, categorizing the teacher's strategy instruction into instruction in memorization strategies, organization strategies, elaboration strategies, and monitoring strategies (see Anmarkrud and Bråten (2012) for a more detailed description of coding schemes, coding procedures, reliability measures, and statistical analysis used in this part of the PISA+ project).

3.3.2 Amount of Instruction in Comprehension Strategies

Across all classrooms, independent of strategy category, instruction in comprehension strategies was observed in 19.7 % of the total instructional time. Instruction of elaboration strategies occurred in 15.1 % of the total instructional time, while instruction in organization strategies, monitoring strategies, and memorization strategies occurred in 2.1 %, 1.3 %, and 1.2 %, respectively, of the total video data. Thus, 80.3 % of the video data from the 16 lessons were coded as 'no instruction of comprehension strategies'. There were substantial differences in the amount of comprehension strategies instruction among the four teachers, however. The students' in Nina's classroom received far more instruction in comprehension strategies than the students in the other three classrooms. In fact, Nina carried out more than half of the instruction in comprehension strategies that we observed in all, mainly as instruction in elaboration strategies. Nina spent 38.9 % of her instructional time on teaching comprehension strategies. While Hannah spent a lesser part of her total instructional time (19.7 %) on comprehension strategies than Nina, she was the one who carried out the majority of the instruction in memorization and organization strategies. Leila (8.1 %) and Monica (9.0 %) were the two teachers who spent the least portion of their instructional time on instruction in comprehension strategies.

Due to the lack of precise reporting of the amount of comprehension strategies instruction in previously published descriptive classroom studies (Allington and Johnston 2002; Pressley et al. 1998, 2007), it is difficult to compare the amount of strategies instruction observed in our study with that observed in earlier studies. However, although prior research does not report on the exact amount of instruction in comprehension strategies, descriptions like "virtually no instruction in strategy use" (Pressley et al. 1998, p. 170), "routinely" (Allington and Johnston 2002, p. 207), and "often" (Pressley et al. 2007, p. 230), when compared to Durkin's (1978/79) findings, suggest a successive increase in the amount of strategies instruction observed in descriptive studies during the last 30 years. Compared to the amount of comprehension strategies instruction included in efficient intervention programs, it seems reasonable to characterize the amount of instruction in one of the classrooms we observed (i.e., Nina's classroom) as relatively large. In the other three classrooms, it could be described as moderate to small.

3.3.3 Instructional Format

As shown by Anmarkrud and Bråten (2012), the observed instruction in comprehension strategies in the four classrooms mainly took the form of whole class instruction (78.6 %), primarily as dialogic whole class instruction, followed by individual seatwork (14.4 %) and group work (7.0 %). Of note is that group work was very little used during comprehension strategies instruction.

A more fine-grained analysis reveals that whole class instruction was the dominant instructional format within each of the four strategy categories. Thus, more than 80 % of the instruction in both memorization and elaboration strategies took the form of whole class instruction, indicating that students received little individual scaffolding support of their use of those strategies. Example 1 can serve as an illustration of a rather typical episode of whole class instruction in the dominant category of elaboration strategies. The teacher (Nina) activates relevant background knowledge by asking questions and giving students hints about the correct answer. The instruction in organization strategies was also dominated by whole class instruction (69.0 %), albeit to a somewhat lesser extent than the instruction in memorization and elaboration. With respect to the instruction in monitoring strategies, this appears to have been more individualized than instruction in the other strategy types, with a relatively large percentage of the instruction in monitoring strategies occurring during individual seatwork (33.3 %) and group work (14.3 %). On the other hand, this difference between the instruction in monitoring and the other types of strategies seems less important given the very small amount of instruction in monitoring strategies that occurred in the lessons we observed.

Example 1: Whole Class Instruction in Elaboration Strategies

Context description: The class is working with the theme of expository prose/non-fiction, and is going to read an article from a conservative daily concerning the government's proposal to remove the compulsory second foreign language in school. Before the students begin to read the article, Nina reviews the characteristics of an article, hence activating important background knowledge.

Teacher:	OK, we will be working on an article today. If I say to you that it's a genre called expository texts or non-fiction, what does that mean? Does anyone know what non-fiction is? It is the opposite of what we call fiction in the literature.
Student 1:	Non-fiction is sort of facts, things that happen in reality. Fiction is more imagination.
Teacher:	Yeah right. Non-fiction is to a larger degree based on facts. But there are many different subgenres in non-fiction. Does anyone know any? I have already said the article.
Student 1:	Writing about your opinion.
Teacher:	Yes, you can write a letter to the editor for example. It's not quite the same as an article, but you express your opinions (. . .). In fiction, what kind of subgenres do we have there? Any suggestions?
Student 2:	Fairytales.
Teacher:	Fairytales yes. Why is fairytales fiction?
Student 2:	Someone has made it up.
Teacher:	Yes, there is someone who has made it up. It has had a different purpose than non-fiction. What is the purpose of fairytales and folk literature? What function do fairytales have?
Student 3:	Entertaining?
Teacher:	Entertaining, yes. Other purposes?
Student 4:	You will learn things.
Teacher:	Yes, you will learn something. (. . .) There is always a moral in fairy tales, so there is something to be learned.

(continued)

[*The teacher and students continue to talk about short stories and novels as examples of other genres of fiction*]

Teacher: Now it's time for non-fiction, first and foremost the article. Think about a newspaper article, and you should probably write this down. Where will you find articles? You can find them in magazines, what kind of magazines? You can find them in 'gossip magazines' like Se og Hør.
Student 2: National Geographic
Teacher: National Geographic, yes. They are far more based on facts.

[*More suggestions for places to find articles proposed*]

Teacher: Critical reading is important when you read an article. What is critical reading?
Student 5: See if they exaggerate.
Teacher: Yeah, and you should look at the linguistic features the author uses. A newspaper article in Aftenposten [*Norwegian conservative daily*] might cover an issue from several perspectives, right? A tabloid would perhaps see an issue from only one side, which is a bit subjective. Good articles include several perspectives and discuss opposing views up against each other, hence making nuances visible for the reader. Let's take a closer look at an article.

Finally, there were substantial differences between the teachers with respect to the use of instructional formats during comprehension strategies instruction. The vast majority of Hannah's (87.2 %) and Nina's (84.6 %) strategies instruction was whole class instruction. In comparison, Leila's strategies instruction varied more between the three formats, with 41.3 %, 39.7 %, and 19.0 % of her strategies instruction taking the form of whole class instruction, individual seatwork, and group work, respectively. Please note, however, that the amount of comprehension strategies instruction occurring in Leila's classroom during the observation period was quite small. Monica, who also provided relatively little comprehension strategies instruction overall, divided her strategies instruction between whole class (58.5 %) group work (41.5 %) formats. Interestingly, Nina, who taught comprehension strategies the most, did not use the group work format at all during this instruction.

Given the results, comprehension strategies instruction as observed in these four classrooms, even when it naturally occurs, may be mainly restricted to whole class instruction. Although the participating teachers seemed to favor dialogic whole class instruction, thus encouraging student initiatives and responses, the limited use of individual and group-based approaches suggests that too little individualized scaffolding support, supervision, and monitoring were provided during comprehension strategies instruction. It should be noted that the whole class format does not necessarily imply passive students or the absence of active meaning construction. Both Pressley et al. (1998) and Allington and Johnston (2002) reported on the occurrence of whole class discussions during comprehension instruction. In Allington and Johnston's study, those discussions were characterized by students collectively adding new layers of meanings and interpretations to texts, in contrast to the IRE interaction pattern (Cazden 1988) often observed in classrooms. Allington and Johnston also observed whole class discussions that facilitated transfer of comprehension strategies across reading situations and tasks, with students making their background knowledge available to each other. Such whole class discussions were not observed in our study, however. Although the teachers we observed allowed for student initiatives during dialogic whole class instruction, this instructional format still seemed to involve a form of teacher control that could seriously hinder collaborative learning.

3.4 Conclusion

A predominance of whole class instruction when teaching comprehension strategies instruction is somewhat disturbing, given the strong emphasis on collaborative learning in the literature. There is a solid research base indicating that collaborative group work can have beneficial effects on students' knowledge acquisition (Johnson et al. 1981; Rohrbeck et al. 2003), for example, by allowing students to share background knowledge and comprehension, as well as to support and challenge each other to justify, defend, or reconstruct their comprehension. Compared to this study, previous descriptive studies of comprehension instruction (Allington and Johnston 2002; Pressley et al. 1998, 2007) report on a much more varied use of instructional format. Thus, in the North American studies, teachers quite frequently used the whole class format to introduce texts, tasks, and strategies, but then students did the actual reading and practicing of strategies individually or in groups, often followed by a joint summarization in whole class format at the end of the lesson. In a Norwegian context, a recent intervention study (Andreassen and Bråten 2011) found that reading-group organization during comprehension strategies instruction represented a particular challenge for Norwegian teachers, which they ascribed to the students' unsatisfactory social skills and lack of independence. The challenge of implementing group work as an efficient instructional format is far from unique to Norwegian teachers, and proficient use of collaborative learning methods seems to require a substantial amount of professional development (Hilden and Pressley 2007). Based on the results of the present study, these four teachers appear to lack the professional knowledge needed to use collaborative learning to its full potential as the catalyst for strategic learning.

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Chapter 4
"Usually We Are Not Where the Teacher Is"

Individualized Teaching Methods in Mathematics Classrooms

Ole K. Bergem

4.1 Introduction

A robust finding in educational research is that student learning is positively affected by *teacher support* and that teacher support is particularly critical for students' engagement in their own learning (OECD 2005; Hattie 2009; Baumert et al. 2010; Bryk et al. 2010), a vital factor for achieving good learning results (Kumar 1991; Boyd et al. 2009; Hill and Grossman 2013). Meichenbaum and Biemiller (1998) argue that teachers, in order to optimize their support of student learning, must take into consideration and be sensitive to the different stages in the learning process, and plan and balance the classroom activities accordingly.

In this chapter, data from both quantitative and qualitative studies conducted in lower secondary schools will be presented, analyzed and discussed from these perspectives. Firstly, the correlation between the PISA constructs *Supportive Teacher* (ST) and *Effort and Perseverance* (EP) will be explored. This examination will be based on regression analysis performed on Norwegian student questionnaire data from the PISA 2000 Study. The main purpose of this analysis is to investigate if these survey data back the notion of the importance of teacher support for students' effort and perseverance. Secondly, the findings obtained in the examination of the survey data will be discussed in relation to an analysis of data from the PISA+ Video Study. The key issue in this analysis is to investigate how individualized instructional methods can affect teacher support for student learning. Particular attention will be given to a specific individualized methodology, which was used in all the videotaped PISA+ classrooms. A central element in this methodology is the use of work plans, a written document that prescribes the work to be done

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by the students within a specific period of time – most often a period of two weeks. Another important element in this methodology is the use of *study lessons*. These are lessons set aside on the weekly schedule in which students are given the opportunity to complete the tasks and assignments from the work plan.

The argumentation in this chapter will be based on empirical observations and analyses of video captures from the PISA+ classrooms, and statements from the student and teacher interviews. Even if all the empirical evidence is taken from the mathematics classrooms in this study, the themes discussed will be relevant in relation to other subjects as well.

As pointed out in Chap. 1, the Nordic countries, including Norway, have a long tradition in attempting to provide equal opportunities for all students by using national curricula and by maintaining a non-streamed and unitary structure of their school system. Furthermore, individualized instructional methods, inspired by ideas related to educational progressivism and philosophically based on principles of equity, have been promoted in Norway for quite some time, backed by key curricular documents (KUD 1997; KD 2006). As equity issues today are seen as one of our key educational challenges (OECD 2013), it seems important to investigate if individualized teaching practices do seem to secure broad learning opportunities for all students. The ambition of this chapter is to make a contribution to this discussion.

4.2 Theoretical Perspectives

4.2.1 Classroom Learning Settings

The science of learning is a very comprehensive area of study, engaging researchers from various fields and with quite different approaches to their object of study. One of the major changes in research about learning conducted during the last few decades is that more research is carried out in complex environments, such as classrooms and everyday settings (Greeno et al. 1996; Mayer and Alexander 2011). Bransford et al. (2006), in their review of learning theories, argue that a more robust understanding of learning can be reached by making synergies of different research traditions. They state that it is particularly important to bring together the different strands of research about learning carried out in relation to educational settings, making it more relevant for the field of practice.

Meichenbaum and Biemiller (1998) link concepts within learning theory to the actual classroom setting, involving teachers, students and relevant artifacts. They argue that classroom learning should include three types of situations or settings, namely *the acquisition setting, the consolidation setting* and *the consultation setting*. The acquisition setting is related to the teacher's introduction of new content material, where the teacher's role is to create an inviting learning environment, prepare students for instruction and provide guidance, monitor and offer feedback. In the consolidation setting a major part of the teacher's responsibility is to carefully plan different practice tasks on which students will have a high success rate, to scaffold and to give calibrated assistance by being sensitive to students’ need for support. Additionally, the teacher should try to bolster students’ self-confidence. The teacher’s role in the consultation setting is mainly to have students engage in self-reflective thinking, to provide opportunities for the students to convey the essentials of the newly learned content to others and explain to peers how to solve different tasks, and to generally stimulate students’ metacognitive competences. Reflection and self-evaluation are continuous parts of these different learning situations, but are especially prominent in the consultation setting. Overall, it is the teacher’s task to balance the various aspects of these three settings in order to stimulate and support student learning. A clear coherence between the different learning situations is strongly recommended. To attain such coherence, the teacher needs to plan the different stages and how the relevant learning activities should be applied, and to simultaneously be responsive to the students’ actions and reactions.

Meichenbaum and Biemiller (1998, p. 118) further argue that the three settings described above can be operationalized in relation to classroom learning processes. They summarize the teacher’s task in the *acquisition setting* in the following four points:

1. Providing advance organizers;
2. Using informed instruction;
3. Accessing and activating the students’ prior knowledge;
4. Assessing the students’ misconceptions that could interfere with their task engagement and performance.

They claim that each one of these points is important in preparing the students for the learning of new subject content. Generally, they argue that a key element in the acquisition setting is to motivate the students to care about learning new material. In the acquisition setting, therefore, the teacher first of all needs to motivate and prepare students for attaining new knowledge and skills through introductions at the beginning of a work session. In such introductions the teacher should provide advance verbal, visual and/or metaphorical organizers and activate students’ prior knowledge of the new theme. Later in the learning process, students must be given opportunities to consolidate their skills and strategies by working, in groups or individually, on suitable and challenging tasks and exercises related to the themes introduced. In their description of the *consolidation setting*, Meichenhaum and Biemiller point out the importance of maintaining coherence with the acquisition setting. In this setting, students should be provided with opportunities to do exercises and tasks related to the themes discussed in the acquisition setting. But while students in the acquisition setting often need continuous support, students who are consolidating skills or strategies need less direct assistance. Two broad kinds of consolidation tasks are listed as:

1. Tasks that emphasize repeated performance of the skill;
2. More complex, applied tasks.

For both kinds of tasks it is important to adjust task difficulty to student abilities. A mismatch will easily lead to reduced learning opportunities and low motivation.

In the final stage, the *consultation setting*, the class should elaborate upon the newly acquired knowledge. Meichenhaum and Biemiller (1998) argue that the consultation setting is first and foremost characterized by the idea that if students are to master a set of skills and strategies, they must go beyond merely responding to the teachers' request and become autonomous learners. In order to achieve this, it is important that they are provided with opportunities to defend and explain their own work and to act as consultants for peers. The students should be afforded an active role in this learning setting. Klette (2007) argues that assisting students in the elaboration process can be done in the *summing up* at the end of a lesson or work session by connecting activities to key concepts, themes and theories within the actual subject and involving students in relevant discussions.

Introductions, *well-planned tasks* and *summing up* can thus be considered to be three important elements in the structure of teacher support for student learning. In the PISA+ Video Study these elements were central factors in our theoretically based foundation for developing coding manuals for analysis of instructional quality.

4.2.2 Protocols Developed for the PISA+ Video Study

The analysis of the video captures in the PISA+ Video Study was done in two stages. Firstly, in order to be able to make comparisons across subjects, a common set of codes and categories was developed and used for all three subjects (Klette et al. 2005). Secondly, an additional protocol was developed for analysis of the science lessons (Ödegaard and Arnesen 2006). The categories in this coding scheme were to a large degree based on the above-presented concepts, developed by Meichenbaum and Biemiller (1998), but were also influenced by research carried out within science education, particularly by Lemke (1990) and Mortimer and Scott (2003). A modified version of this coding scheme was later used in the analysis of the mathematics lessons (Ödegaard et al. 2006). All the protocols used in the PISA+ Video Study were structured using a certain number of main elements or categories. The one used for mathematics comprised seven such elements. Each element then had a number of sub-codes. "Teaching activities" was one of the main categories in this coding scheme and in Table 4.1 the eight sub-codes of this category are presented and related to Meichenbaum and Biemiller's three types of settings for classroom learning.

As can be seen in Table 4.1, all the eight codes can be linked to Meichenbaum and Biemiller's three types of settings, three to the acquisition and consultation setting and two to the consolidation setting.

Table 4.1 The sub-codes for the element “teaching activities” in the mathematics protocol in the PISA+ video study

	Code	Explanation	Setting
1	Review	*Teacher summarizes or asks questions about themes from previous lessons*	Acquisition
2	Motivation, appetizer	*Teacher uses an artifact or an exciting problem to collectively motivate student interest in a new topic*	Acquisition
3	Teacher summary	*Teacher summarizes the work done in the lesson*	Consultation
4	Going over the “do now”	*Attending to common questions related to the work done during the lesson*	Consultation
5	Going over the homework	*Attending to questions related to homework, rehearsing*	Consultation
6	Developing new knowledge	*New knowledge is developed*	Acquisition
7	Developing new practical skills	*Mathematical knowledge is applied to a practical problem*	Consolidation
8	Offer seatwork	*Students are doing seatwork*	Consolidation

In the next paragraph, the work plan methodology often used in Norwegian lower secondary classrooms will be briefly presented.

4.2.3 Work Plan Methodology

Work plans can be defined as a written document, usually developed and prepared by the teacher, who prescribes the learning activities and tasks students are expected to perform within a specified period, often two or three weeks. Work plans have been used in Norwegian primary and lower secondary schools since roughly the mid-1990s, to the point where the majority of teachers now use this pedagogical tool. In a student survey from 2009, more than 60 % of lower secondary Norwegian students confirmed that they used work plans (Skaalvik and Skaalvik 2009). That the use of work plans is widespread in Norwegian lower secondary classrooms is also confirmed by other sources. In the PISA 2012 School Questionnaire, more than 80% of the headmasters from the participating schools reported that work plans were frequently used by their teachers.[1]

Work plans have a rather vague and weak theoretical foundation, but it is assumed that different educational reform initiatives linked to educational progressivism, the ‘integrated day’ (Taylor 1972) and policies for differentiated learning (KUD 1997; KD 2006) have inspired the development of the Norwegian work plans

[1]Unpublished information from the Norwegian PISA 2012 data file.

(Bergem and Dalland 2010). Klette (2007) and Dalland and Klette (2014) emphasize that the work plan is first and foremost a practical tool that enables educational differentiation and a more flexible organization of the weekly schedule. The last point is particularly realized through the use of *study lessons*. In these lessons the students themselves can decide what to do, the idea being that they should do assignments from the work plan under teacher guidance. Providing work plans and study lessons is generally meant to empower the students by allowing them to plan their learning activities to a greater extent, and in this way getting them more involved in their own learning processes.

4.3 Data and Methods

The analysis in this chapter is based on data from the mathematics classrooms in the PISA+ Video Study and survey data from PISA 2000. In the following section, a few key elements regarding these studies will be presented. A more thorough presentation of the design and methods used in the PISA+ Video Study is given in Chap. 1. For a comprehensive portrayal of the PISA study, see the Norwegian national reports (Lie et al. 2001; Kjærnsli et al. 2004; Kjærnsli and Roe 2010).

4.3.1 PISA+ Video Study

As described in Chap. 1, the main empirical data in the PISA+ Video Study consists of video recordings, field notes, copies of students' work and interviews with students and teachers. All the video-filmed mathematics lessons ($n = 38$) were analyzed on the basis of protocols developed in this study (Klette et al. 2005; Ödegaard et al. 2006) and some of the results from this coding will be used in the analysis in this chapter. An additional data source is excerpts from student interviews ($n = 31$) and teacher interviews ($n = 11$) that were conducted in relation to the video-captured mathematics lessons. Interview quotes presented in this chapter are selected on the basis of two criteria; their relevance to the themes and problems being discussed and their representativeness for the students' and teachers' points of views, as expressed in the total sample of interviews collected in this study.

4.3.2 PISA

The two PISA constructs analyzed in this chapter (Effort and perseverance and Supportive teacher) both consist of a group of statements, four and six, respectively, that students are asked to evaluate. By using a certain number of statements, each covering slightly different aspects of the actual construct, one can meet reasonable demands on both construct validity and reliability. Students' responses are related to a scale of frequency for each statement, and the students' scores on each particular construct appear as an aggregated index calculated from answers to each individual statement. While high construct validity requires that the various aspects of the actual theoretical construct are reasonably well covered by the statements taken together, reliability is often measured using the so-called Cronbach's alpha coefficient (Crocker and Algina 1986). The latter is calculated from the consistency of students' responses to the different statements measuring the construct. Cronbach's alpha indicates how much the actual statements have in common and which therefore are not based on pure chance by the specific statements selected to represent the construct. An alpha above 0.70 is generally considered to provide sufficiently high reliability for a construct. Cronbach's alpha for the two PISA 2000 constructs analyzed in this chapter, are respectively 0.81 (EP) and 0.79 (ST).

4.4 Findings

4.4.1 Description and Analyses of the Applied PISA Constructs

To calculate the values of the various constructs that are measured in PISA, an international scale with mean 0 and standard deviation 1 for individual students in the OECD area is most commonly used. This scale is applied for both of the PISA constructs presented in this chapter, Effort and Perseverance (EP) and Supportive Teacher (ST).

The values of EP are calculated from students' responses to the following four statements, where students are asked to tick off one of the alternatives: *almost never, sometimes, often, almost always*:

1. When I do schoolwork, I work as hard as I can.
2. When I do schoolwork, I continue to work even if the problem is difficult.
3. When I do schoolwork, I try to do my best to gain new knowledge and skills.
4. When I do schoolwork, I do my best.

A 4-point Likert scale is used and the Norwegian mean value for this construct is relatively low. Norway is, however, among the OECD countries in which this construct has the strongest positive correlation with student test score, about 0.25 (Lie et al. 2001). Consequently, an interpretation of these data can be formulated as follows: *Norwegian students are characterized by having relatively low scores for effort and perseverance. Simultaneously, this factor is particularly important in Norway in relation to students' academic performance*.

1. The teacher shows interest in the individual student's learning.
2. The teacher gives students the opportunity to express their opinions.
3. The teacher helps students with their work.
4. The teacher continues to explain until students understand.

5. Teachers do a lot to help the students.
6. The teachers helps students to learn.

The Norwegian mean value for this construct (−0.03) by far the lowest among the Nordic countries, though just barely below the OECD mean (0). However, for this particular construct, Norway has the highest positive correlation with students' test scores of all OECD countries participating in PISA, namely 0.15 (Lie et al. 2001). An interpretation of these data is as follows: *As perceived by the students and from a Nordic perspective, Norwegian teachers provide relatively little professional help and support in their lessons. At the same time, teacher support seems particularly important for student achievement in Norway.*

A crucial question now seems to be whether the apparently weak teacher support influences students' effort and perseverance. This can be evaluated by analyzing the correlation between the two PISA constructs, ST and EP. Figure 4.1 shows the graphical relationship between ST and EP with 95 % confidence intervals. For this analysis, the students are divided into four equal groups based on their values on the ST construct. Group 1 consists of the quartile of students (0–25 %) who experience the least teacher support; groups 2 and 3 consist of the two quartiles of students (26–50 % and 51–75 %) with consecutively rising values for teacher support, and group 4 consists of the quartile of students reporting the highest levels of teacher support. The vertical axis is ordered by stepwise and increasingly higher values for the EP construct.

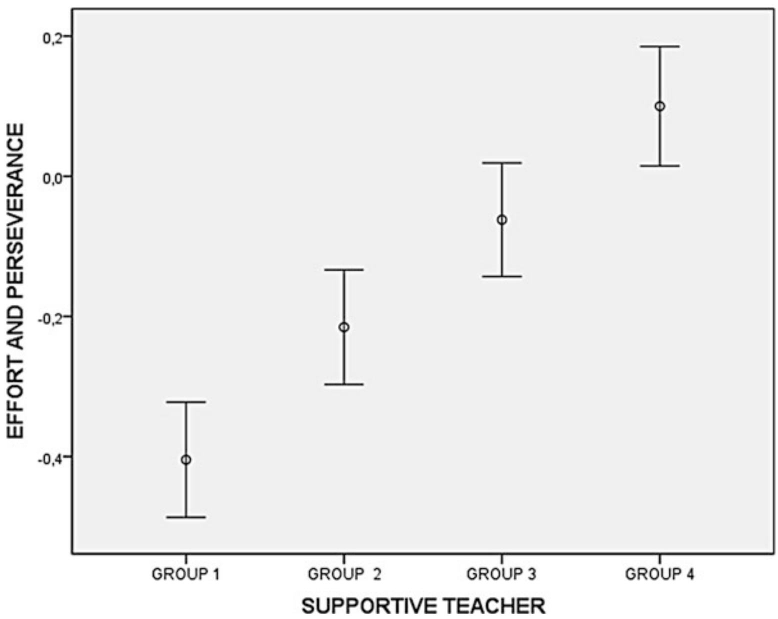

Fig. 4.1 Correlation between the PISA constructs ST and EP for Norwegian students, grouped by quartile levels for the construct Supportive Teacher

Figure 4.1 indicates a clear positive correlation between the degree of teacher support and students' academic effort and perseverance. Students' effort and perseverance increases step by step following higher reported teacher support.

4.4.2 Analyses of Data from the PISA+ Video Study

In the next section, data from the PISA+ Video Study will be analyzed with the purpose of complementing the PISA findings that have been presented above. The analysis will be framed in relation to Meichenbaum and Biemiller's (1998) theories about the importance of structuring students' learning experiences, i.e. that the teacher systematically orchestrates the various learning settings.

4.4.3 Work Plan Methodology: The Acquisition Setting

So, how was the acquisition setting handled in the mathematics classrooms in the PISA+ Video Study?

As previously stated, all of the 38 video-captured mathematics lessons in this study were coded using protocols developed by the participating researchers. One main category in the protocol developed for mathematics (Ødegaard et al., 2006) was labeled *teaching activities*. In Table 4.2 the percentages of codes under this category are presented for each of the participating classrooms.

As can be seen in Table 4.2, *developing new knowledge* was the most frequent activity in Class 2 and the second most frequent activity in three of the other five classrooms. In developing new knowledge, which in Meichenbaum and Biemiller's analytical scheme belongs to the acquisition setting, the observed mathematics teachers would typically try to get the students involved by asking questions, inviting them to participate in a classroom dialogue. All the six mathematics

Table 4.2 Percentages of activities under the main category "Teaching activities" in the six mathematics classrooms in the PISA+ video study

Codes	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Total
1. Review	3	8	32	7	3	34	87
2. Motivation, appetizer	1	1	4	2	16	0	24
3. Teacher summary	0	0	0	5	2	0	7
4. Going over the "do now"	0	0	0	3	0	1	4
5. Going over the homework	0	0	0	29	14	6	49
6. Developing new knowledge	21	52	0	22	20	2	117
7. Developing new practical skills	0	0	14	2	0	0	16
8. Offer seatwork	74	38	44	30	46	57	289

teachers in the PISA+ Video Study applied such dialogical instruction to a high degree. This can be interpreted as an attempt to '*access and activate the students' prior knowledge*', one of the central points in Meichenbaum and Biemiller's portrayal of the acquisition setting.

Meichenbaum and Biemiller also emphasize the importance of motivating students. To what degree the mathematics teachers were inclined to use appetizers to motivate their students was also categorized in our study and the results can be seen in Table 4.2 under the code 'Motivation, appetizer'. This code is explained as: 'teacher uses an artifact or an exciting problem to collectively motivate student interest in a new topic'. However, to get a more accurate picture of how often the teachers actually used appetizers, a more detailed analysis of the frequency of this activity is presented in Table 4.3.

As can be seen from Table 4.3, 'motivation/appetizer' was used in 10/38, or about 26 % of the mathematics lessons in the PISA+ Video Study, unevenly distributed between the six classrooms. However, except for classroom 5, very little time was used on this activity. There might be several explanations for this. One reason could simply be that in some lessons students were in a different stage of the learning process (consolidation or consultation setting) and that new themes were not introduced. A different explanation, related to the use of work plan methodology, also seems plausible. As a consequence of the use of work plans, students were often working on different tasks and exercises, i.e. they were not always thematically synchronized. This is expressed in the following excerpt from a student interview:

Interview 1

Interviewer: But when you are doing work in mathematics lessons, sitting in pairs, are you working on the same tasks?

Lise/Anne: No.

Interviewer: So you're working on different tasks?

Anne: Some are ahead and some are behind (in relation to the teacher's review)

Interviewer: Yes

Lise: . . . some are at the same place.

Table 4.3 Frequency of the use of motivation/appetizer in the mathematics classrooms in the PISA+ video study

Classroom	Number of lessons being video filmed	Number of lessons in which motivation, appetizer were used	Minutes used on motivation, appetizer (in avg.)
1	3	1	1
2	7	1	2
3	7	3	3
4	10	2	2
5	7	3	10
6	4	0	–
Total	38	10	

The student statements in Interview 1, confirming that the students were often unsynchronized with the teacher review, seem to support the assumption that the use of work plan methodology would generally make it less pertinent to apply appetizers that would be relevant for all the students.

4.4.4 Work Plan Methodology: The Consolidation Setting

All the work plans used in the classrooms participating in the PISA+ Video Study had elements of differentiation. In most cases differentiation was related to the amount of tasks and exercises the students were supposed to complete, but in some cases it was also connected to task difficulty (Bergem 2009). However, the self-pacing that work plan methodology stimulates had some peculiar consequences relating to the coherence between the theoretical issues discussed and the tasks performed. Very often reviews of new subject content were followed by working sessions in which many students were occupied with tasks that were not related to the themes and issues just discussed. The following interview excerpt illustrates this point:

Interview 2

Interviewer:	If the teacher takes you through some theme on the blackboard, do you afterwards work on related exercises, or?
Anders:	Yes
Interviewer	… or do you just continue doing exercises from the work plan?
Anders:	It all depends…
Bendik:	We usually start doing exercises…
Anders:	Yeah, I just continue where I left…
Interviewer:	Where you left on the work plan?
Anders:	Yes, usually we are not where the teacher is.

The two students clearly state that it is where they happen to be on the work plan that determines what tasks and exercises they start to work on even after a review of a new theme. According to the students, it is rather rare that this coincides with the teacher’s planned progression of the subject content. This makes the relationship between the acquisition and the consolidation setting quite weak and it seems to be a direct consequence of using work plan methodology. Decoupling activities and tasks from relevant instructional practices, as here described, may lead to a fragmentation of the students’ learning experiences. Tasks and activities can easily be experienced as isolated incidents with a weak connection to important theoretical framing, and this may severely reduce the actual learning outcome. Obviously, this is not planned for, but must be considered to be an unintended consequence of this way of organizing student work.

There are also other points connected to the consolidation setting worth mentioning. Several of the statements that make up the construct SL in PISA are related to the teacher giving academic guidance and assistance to the students. One of the observations made in the PISA+ Video Study was that in the study lessons, when students were working on academic tasks and exercises, teachers with relevant expertise and competence were not available to give adequate guidance and support (Bergem 2009). This is clearly expressed in the following excerpt from an interview where the student has just described using parts of the study lesson to work on tasks in mathematics:

Interview 3

Jon:	Now, I spent half an hour, or I spent half the study lesson to complete half of my assignments in mathematics.
Interviewer:	Ok, so you spent half an hour, and then you completed half of it?
Jon:	Yeah, because, it got worse, more difficult, division and multiplication and stuff. So it was a bit difficult. And I had to understand it all.
Interviewer:	Yes, but did you get any help from the teacher?
Jon:	Yeah.
Interviewer:	But, there was no math teacher there?
Jon:	No, but there was a Phys. Ed. teacher and an English teacher.
Interviewer:	And they could help you?
Jon:	Yes.
Interviewer:	So you understood everything?
Jon:	Well, I didn't get much help from the English teacher, but the Phys. Ed. Teacher helped me.

All schools or classes that organize study lessons must take many factors into consideration when allocating teachers for these lessons, for instance the teachers' weekly schedules and their various duties and tasks. Economic costs must also be taken into account, and there will usually be only one or two teachers available in these lessons to guide the students. Naturally one or two teachers will not cover all the competences needed for giving guidance to all students in all subjects, which means that many students do not get the support they need from professionally competent teachers during study lessons. In spite of these logistical puzzles, it is problematic if students consistently do not get adequate support during this phase of their consolidation setting. This is especially challenging when study lessons constitute a significant part of the weekly schedule. At one of the classes in the PISA+ Video Study there were eight study lessons of 30–45 min a week.

4.4.5 Work Plan Methodology: The Consultation Setting

A summary at the end of a lesson or in the final stage of a thematic working period is an important aspect of the consultation setting (Meichenbaum and Biemiller 1998). In such summaries, the students should be stimulated and guided by the teacher to evaluate different aspects of their learning session, i.e. how the activities they have been involved in are related to central categories or themes, the interrelation of different content areas, etc. Analysis that has been conducted on the PISA+ video data reveals that summaries at the end of a lesson were seldom carried out (Klette & Ödegaard, 2012). Whether this was due to the use of work plans or not is clearly difficult to decide. However, it may seem less relevant to make summaries when the students are occupied with different tasks and activities, depending on their working pace and their general strategies for handling the work plan.

Another aspect of the consultation setting is to afford students opportunities to engage in self- reflective thinking and to participate in high level discussions with peers. So how did the different elements in the work plan methodology seem to be in line with these thoughts? A principal idea behind the work plan methodology is to empower the students by giving them opportunities to make decisions related to their work situation in school. This is conceived as potentially heightening student motivation and learning. However, based on the analysis of the mathematics lessons in the PISA+ Video Study, the increased student influence seemed mainly to be related to organizational features, i.e. what, when and how to work on subject related tasks, and was to a lesser degree linked to developing broader and deeper meta-cognitive or subject-related competences. For instance, it was observed that very little time was used on group work in which students would have opportunities to explain their work for fellow students and be involved in consulting peers. In fact, only in about 5 % of the time allocated to mathematics was group work applied. Thus far from promoting subject-based learning, the use of work plan seemed to lead to an emphasis on individual seatwork at the expense of other methods of working.

4.5 Discussion: Implications for Practice Field

Many educational researchers argue that raising levels of student effort and perseverance are essential for improving student learning outcomes (Marzano 2003; Hattie 2009). The analysis of the selected PISA constructs in this chapter indicates that teacher support is a substantial factor in increasing effort and perseverance among Norwegian 10th grade students. The importance of teacher support is also highlighted by Meichenbaum and Biemiller (1998). They argue that such support needs to be conducted systematically. By structuring the learning situations in an ordered way, they claim that the students can be afforded optimal support in relation to developing key competences.

In light of these empirically and theoretically based statements about the value of teacher support, some of the presented findings from the current analysis are quite alarming. According to this analysis, the use of work plans systematically influenced the structure of the teaching situations in a way that constrained the teachers' opportunities to support student learning. Introductions and summing up were made less relevant by the fact that students' work was not synchronized with the taught topic, and individual seatwork was prioritized at the expense of collective ways of working with subject matter.

Even though the sample of classrooms in the PISA+ Video Study is limited, there are reasons to believe that these findings are relevant within a broader context. Similar effects of work plans on student learning experiences are also reported and commented upon in other recent studies from Norwegian primary and lower secondary classrooms (Olaussen 2009; Helgevold 2011).

Providing equal opportunities for all students and moderating the effect of students' social economic status are highly prioritized goals within the Norwegian educational system. Optimizing teacher support is considered by researchers to be a crucial factor for success in attaining these ambitious objectives (Hattie 2009; Baumert et al. 2010). Maintaining teaching and learning practices that diminish teacher support is therefore clearly not to be recommended. However, complementary analysis of the different aspects of extensive use of individualized teaching methods should be carried out in order to broaden our understanding of the consequences of prioritizing this teaching approach.

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Chapter 5
Teachers' Use of Questions and Responses to Students' Contributions During Whole Class Discussions: Comparing Language Arts and Science Classrooms

Emilia Andersson-Bakken and Kirsti Klette

5.1 Introduction

The aim of this chapter is to explore how teachers use questions as an instructional tool in science and language arts classrooms, and how these questions enable dialogue between teachers and students and support student learning. The focus will be on investigating teachers' use of questions and responses as an instructional tool during whole class sessions. There are many research reports on teachers' use of questions as a key instructional tool (Barnes 2008; Chin 2007; Croom 2004; Mehan 1979) and also on how classroom dialogue is crucial to facilitate learning (Alexander 2008; Juzwik et al. 2008; Lemke 1993; Mercer and Littleton 2007; Nystrand et al. 1997). In this respect, scholars agree that teachers' questioning can significantly improve the students' performance. The analyses presented in this chapter draw on video recordings from teacher-led whole class instruction in lower secondary language arts and science classrooms. We are interested in exploring the *role* and *type* of teacher questions in these two distinct, and rather different, subject areas.

There is a growing consensus among researchers that dialogue, and especially open-ended questions and discussions, makes a difference to student engagement and learning (Alexander 2008; Juzwik et al. 2008; Mercer and Dawes 2008). Although the relationship between question types and the following discussions during whole class sequences is well documented (Almeida and Neri de Souza 2010; Applebee et al. 2003; Mortimer and Scott 2003; Myhill 2006; Nystrand et al. 1997), the use and functions of the different types of teacher questions during whole class sessions are less well studied. Croom (2004) argues that teacher questioning is the most widely used instructional tool during whole class sessions. According

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to Chin (2007), the purpose of teacher questioning in whole class sequences is to assess what the students know. The teacher mainly asks closed questions, Chin argues, and they are mostly information-seeking and require predetermined and/or rather short answers. Lemke (1993), on the other hand, shows how a series of teacher questions in science classrooms build semantic links that are crucial for the students' understanding of the topic. Recently, Juzwik et al. (2008) and Ødegaard and Klette (2012) have emphasized how teacher-led instruction and teachers' careful use of different question types can optimize the dialogic potential of classroom discourse by opening the floor to students' ideas and responding to competing voices. In this chapter, we will explore the potential for student engagement and learning through teacher questioning and student response in whole class sessions in language arts and science lessons. We start by giving a general overview of discourse features and the role and function of teacher questioning during whole class sequences, followed by a short summary of the role of questioning in language arts and science classrooms. Building on this overview, we present our analytical framework for analysing teachers' use of questions in the videotaped classrooms. We then present methods, data, and results, along with a final discussion on how teachers' questions might support and optimize student learning.

5.2 Question–Answer Sequences in the Classroom

Question–answer exchanges between teachers and students clearly dominate whole class instruction in most subject areas; including science and language arts classrooms (Almeida and Neri de Souza 2010; Lemke 1993; Mercer and Dawes 2008; Myhill 2006; Nystrand et al. 1997: Osborne and Chin 2010). Cazden (2001) argues that, at their best, teacher questions can both assist and assess student learning. Questions play a key role in illuminating, explicating, and legitimating student voices in the classroom conversation. As such, questions significantly regulate the extent to which teacher–student interaction can be dialogic and show how responsive teachers are to students' utterances (Mortimer and Scott 2003; Nystrand et al. 1997). Croom (2004) shows that teachers use questions as one of their main tools in the classroom. According to Croom and Stair (2005), teachers use questions primarily as a tool for classroom management, despite the fact that questions are not well suited for this purpose. Teacher questions, these scholars argue, are best used as a diagnostic tool to indicate a student's academic progress or to assess a students' critical thinking (Croom and Stair 2005).

As indicated above, a number of scholars claim that the quality of classroom conversation is crucial for student learning (Cazden 2001; Lyle 2008; Mortimer and Scott 2003; Nystrand et al. 1997). However, research suggests that teachers may find it difficult to promote the type of high quality questions that contribute to student learning (Barnes 2008; Littleton and Mercer 2010). Mercer and Littleton (2007) distinguish between authentic questions, which are questions without pre-specified answers and are open to different interpretations, and closed questions or test questions, where the teacher knows the answer beforehand. They argue that authentic questions are particularly suited for developing students' thinking in specific subject areas. Nystrand et al. (1997) posit that authentic questions are questions to which the teacher does not have a pre-specified answer, signalling to the students that he or she is interested in what they think and know about a certain topic. Furthermore, these questions are used by the teacher to draw out the students' ideas and initial levels of understanding, and the interactions with the students are used as opportunities to encourage them to make explicit their own thought processes (Alexander 2000; Mercer and Littleton 2007).

Several studies describe the most frequent communication structure in classrooms as 'initiation response–evaluation/feedback' (IRE/F) patterns (Cazden 2001; Mehan 1979), triadic dialogues (Lemke 1993; Nassaji and Wells 2000), and reciting conversations (Nystrand et al. 1997; Wertsch 1998). The IRE/F pattern has often been described as the ultimate example of a non-dynamic and non-interactive form of teacher–student communication. However, recent studies challenge this assumption. Emergent studies from Nordic and North Atlantic classrooms suggest that whole class instruction within an IRE/F format provides possibilities for student initiatives and questions, thus giving the students a more active and engaged role (Emanuelsson and Sahlström 2008; Klette 2010; Ødegaard and Klette 2012), facilitating student participation (Aukrust 2003; Bjørnestad 2009; Nassaji and Wells 2000), and providing opportunities for building on the students' perspectives and understanding (Juzwik et al. 2008; Lemke 1993). Thus, IRF/E patterns provide the students with a more active and less restricted role than suggested in earlier studies. Scholars also emphasise how IRE/F patterns serve as semantic lenses for content-focused learning (Alexander 2000; Lemke 1993), and argue that teachers' use of 'revoicing' (Stein et al. 2007) and 'recapturing' (Furtak and Shavelson 2009) serves as a powerful scaffolding technique to ensure substantial learning in subject areas such as science.

Croom and Stair (2005) suggest that teachers use questions as their main tool for managing the classroom, even though questions are not suited to this function. Teachers are concerned with making certain that the class is engaged in the lesson and preventing disciplinary problems; hence, they turn to questions as a tool to manage the classroom discourse. Thus, teachers often fling question after question at the class in the hope of engaging the students. Croom and Stair argue that this often has the opposite effect. They contend that three things may happen when a teacher poses a question to the class. First, the student who knows the answer may blurt it out before anyone else has had a chance to think about it. Second, a student who craves attention may offer an answer even though he or she is ignorant about the correct answer. Third, students who are insecure about their academic ability, or who have difficulty understanding the subject matter in question, will not attempt to answer.

Questions of wait-time – the amount of time teachers should wait for students to provide responses to their questions – have been studied by Tobin (1986) and others. Tobin suggests that extended wait-time reduces the utterances per time unit and the number of times the teacher interrupts the student discourse. Furthermore, his study showed a difference in teacher questioning, with teachers in extended wait-time classes asking more appropriate questions and their students being more likely to respond to teacher solicitations. Following Rowe (2003), the average wait-time for a response to a question is one second and the teacher's response to the student's answer is usually less than a second.

Thus far, we have discussed the role of discourse features and teacher questions in relation to lower secondary classrooms in general. We now turn to teacher questions in science- and language arts classrooms. From studies of language arts classrooms, Nystrand et al. (1997) claim that if we change the discourse pattern from IRE to IRF, there is a greater potential for dialogue, but this requires that the teacher gives feedback (F) that pushes the student's contribution further, rather than simply saying "good" or "good idea". The teachers' follow-up must be validated in such a way that it affects the direction of the discussion that follows, Nystrand et al. argue. In a more recent study, Juzwik et al. (2008) show that teacher monologues can be transformed into dialogues by giving a more substantiated evaluation and opening the floor to students' ideas. Nystrand et al. (1997) emphasise that much can be learned about teacher–student interaction in the classroom by looking more closely at the type of questions that are asked, the extent of authenticity in the questions, how they support student participation, and whether they allow for alternative interpretations or provide disagreement.

Lemke (1993) claims that the most common activity structure in science classrooms is the triadic dialogue, which consists of a three-part question–answer–evaluation pattern. He argues that the most important and clear thematic development strategy used in triadic dialogue is that of the teacher question series. In using this strategy, Lemke states, the teacher plans a series or sequence of thematically interconnected questions, which, as a whole, build a set of semantic links that are important to the thematic focus. As long as the students provide the thematically correct answers, the triadic dialogue provides efficient descriptions of thematic relations. It is the teacher, however, who decides which questions are asked and which answers are accepted, and students have few opportunities for posing their own thematic initiatives in this communication structure (Lemke 1993).

Drawing on the work of Bakhtin (1953), Vygotsky (1978), Lemke (1993) and others, Mortimer and Scott (2003) distinguish between four dimensions of communicative approaches in science classrooms: (a) interactive/dialogic; (b) non-interactive/dialogic; (c) interactive/authoritative; and (d) non-interactive/authoritative. In the interactive/dialogic pattern, the teacher and students explore different ideas and work together. In non-interactive/dialogic communication, the teacher, as the primary agent, reviews and summarizes ideas and views that have been pointed out during the lesson, but also provides time for disagreements and competing perspectives and questions. In the interactive/authoritative dimension, the teacher has a set agenda for the lesson and this often leads to an IRE/F-structured question–answer pattern. In the non-interactive/authoritative dimension, the teacher presents a view through lecturing and there are limited possibilities for students to raise their voices and posit alternative viewpoints and questions. Using these dimensions, Mortimer and Scott show that any effective teaching lesson should include both dialogic and authoritative discourses, achieved in both interactive and non-interactive ways. Mortimer and Scott (2003) argue that when the teacher is teaching in an interactive/dialogic communication pattern, the chains of interaction between the teacher and students lengthen. This means that the teachers ask more open questions and give more responses that are aimed at giving feedback, rather than evaluating the students' answer.

As outlined in this short overview, teachers can use questions for several purposes. One purpose is to legitimize a student's voice by asking follow-up questions. A teacher can also ask questions in order to probe students' interpretations. Another form of questioning is when the teacher asks test questions, which are aimed at determining what students know about the subject. Questioning can also be used as a method of classroom management. Finally, questions are used to probe the students' understanding and gather information about what and how students are thinking.

Despite teachers' use of questioning as a major instructional tool, we still know little about the form and function of teacher questions in the classroom, both in general and in relation to the different subject domains. In this article we have chosen to use science and language arts classrooms as lenses to investigate teachers' use of questions based on the distinct differences in teaching traditions in these two subject areas. In the language arts classrooms, many activities are related to the interpretation of different texts and genres (Applebee et al. 2003; Grossman and Stodolsky 1995; Hultin 2006; Skarðhamar 2011), while science teaching is closely linked to working methods central to science as an academic discipline such as the 'nature of science', inquiry methods and scientific argumentation (Mortimer and Scott 2003; Newton et al. 1999). Science, as a field of expertise, is also often described as a predefined and fixed body of knowledge (Newton et al. 1999), nurturing test questions and questions that require a yes or no answer. The differences in these two subjects can also be traced in their textbooks. Maagerø and Skjelbred (2010), for example, show how textbooks for eighth grade science students are dominated by yes–no questions. Knudsen and Mortensen-Buan (2010) claim that in language arts textbooks the questions and tasks have a rather open form. An open inquiry form is used, they argue, to allow the reader to interpret and reflect upon different types of texts and text genres.

Drawing on the overview presented above, we are interested in exploring the following research questions with regard to teachers' use of questions during whole class instruction:

1. What type of questions do teachers ask in science and language arts classrooms?
2. Is there a typical pattern for the use of 'open' or 'closed' questions?
3. What patterns of teacher responses during question–answer sequences can be identified?
4. What are the differences between the roles of questions in the two subject areas?

5.3 Methods and Data

The data sources build on videotaped classroom observations from the lower secondary level. The video material is drawn from the PISA+ Video Study (see Introduction to this book). The material constitutes 45 videotaped lessons from science classrooms and 44 videotaped lessons from language arts classrooms. The current analyses draw on video observations from eight science lessons and 10 language arts lessons ($n = 18$). The 18 (8 + 10) lessons selected were chosen on the basis of the extent of whole class teaching implemented in these classrooms. Whole class teaching is defined as an instructional process wherein teachers pose questions, deliver lectures and conduct other related activities to an entire class. More lessons in language arts were selected because whole class teaching was generally implemented to a lesser extent in language arts classrooms than science classrooms (Ødegaard and Klette 2012). So, to equalize time spent on whole class teaching in both subjects, two more lessons were selected from language arts. In the 18 lessons (810 min) analysed, 430 min were devoted to whole class teaching (i.e. altogether approximately 53 % of these lessons).

The data were coded with reference to an applied version of Furtak and Shavelson's (2009) coding manual from science classrooms (see next section for a presentation of this framework). This manual was developed for analysing the use of inquiry-based methods in science classrooms, while we have used it for analysing teachers' use of questions in both science and language arts classrooms during whole class interaction. With reference to Mortimer and Scott (2003), Furtak and Shavelson also make the distinction between dialogic and authoritative teaching moves. Within these two main teaching styles, patterns of teachers' response and questions to students were investigated.

5.4 Analytical Framework

Our analytical framework builds on the dialogic and authoritative teaching moves as outlined by Scott (1998) and Mortimer and Scott (2003), and later developed by Furtak and Shavelson (2009). In the analyses we use '*Dialogic Teaching Moves*' and '*Authoritative Teaching Moves*' as two main categories when analysing teachers' use of questions and responses during whole class sequences. '*Dialogic Teaching Moves*' covers issues such as 'asking 'real' and open questions', 'revoicing/reflecting student responses', and 'providing neutral responses to students', while '*Authoritative Teaching Moves*' conveys responses from teachers such as 'sequence of repeated questions', 'reconstructive paraphrase or recap', and 'cued elicitation of students' contributions'. Tables 5.1 and 5.2 describe the categories in more detail.

We do not choose to use the terms dialogic and authoritative as binary concepts (Clarke 2006; Andersson-Bakken in press), but are interested in the teachers' use, pace, and rhythm when organising whole class learning through questioning. Like Mortimer and Scott (2003), we see the dialogic and authoritative teaching moves as two different teacher activities; hence, they are used as distinctions and not as dichotomies.

Table 5.1 Dialogic teaching moves

Dialogic teaching moves – teacher and students jointly construct narrative/discussion	
Asking 'real' or open questions	Teacher asks a question of a student or entire class to which the answer is not necessarily known or expected by the teacher
Revoicing/reflecting student responses	Teacher repeats verbatim what a student has responded without changing or altering the meaning of the statement. Includes when a teacher repeats in a question-style format or asks student to clarify what she/he said, or to refer that comment to another student
Providing neutral responses to students	Teacher repeats student responses, or provides comments that do not indicate whether students' statements are correct or incorrect

Table 5.2 Authoritative teaching moves

Authoritative teaching moves - teacher controls course of narrative/discussion	
Cued elicitation of students' contributions	Teacher asks questions while simultaneously providing heavy clues, such as the wording of a question, intonation, pauses, gestures, or demonstrations, to the information required
Sequence of repeated questions	Teacher asks the same/similar questions repeatedly to seek a particular answer, and continues asking the question/s until answer is provided by students
Reconstructive paraphrase or recap	Teacher recasts or paraphrases what students has said in a more complete or acceptable form, or in preferred terminology, including when teacher adds to or changes the meaning of what the student has said
Providing evaluative responses	Teacher clearly indicates, through words or intonation, that a student's comment is correct or incorrect

5.5 Analysis

The videos were coded using the Videograph software program (Rimmele 2002) and were coded at 5 s intervals. Videograph allows the researcher to see the videos of the teacher and the students simultaneously. The software also allows for stopping the coding and re-coding as often as necessary. In addition, using a video camera and a software program, such as Videograph, provides opportunities to test the codes with others and see if several researchers have coded the same segment with the same codes. This enhances reliability and transparency in the current analyses.

The codes we used in Table 5.1 to capture dialogic teaching moves are: 'asking 'real' or open questions', 'providing neutral responses to students', and 'revoicing/reflecting student responses'. While the first code addresses questions directly, the others focus on teachers' responses to students. The codes that we have selected to illustrate authoritative teaching moves in Table 5.2 are: 'cued elicitation of students' contributions', 'sequence of repeated questions', 'reconstructive paraphrase or recap', and 'providing evaluative responses'. All of the codes address questions and responses to students by the teacher. As we coded at 5 s intervals, each question is not accounted for; rather, the code that takes up most of the interval is coded. We chose to code at 5 s intervals because most codes can be delivered by the teacher or the student in this time frame. If we had chosen a longer time frame, we would have missed several teaching moves, for example, where two codes occurred in rapid succession. On the other hand, with a shorter timeframe we would not have been able to catch what was said in the utterance. As a starting point, we looked at the whole sequence of one lesson to identify possible sequences for further analysis. We used the entire 5 s interval to apply the appropriate code, if any, for that statement. For example, if the teacher in those 5 s asked the students "What kind of books do you read?" this was coded as 'asking 'real' or open questions'.

The sequence below illustrates an example of our coding method. It is from a science lesson and the class is talking about the skeleton and the muscles. This incident is at the beginning of a lesson, and the teacher asks the students how they think human beings evolved (all direct quotes translated by the authors).

Excerpt	Code
Teacher: If we imagine how human beings were from the beginning of evolution, what do you think a human being was like then, where do we come from? How have we become the way we are? Is there anyone who has any ideas about that? The earth has not always been populated by people like us. Yes Andreas?	Asking 'real' or open questions
Student 1: We were monkeys	
Teacher: You imagine that we used to be monkeys, yes, that they are our ancestors?	Revoicing/reflecting student responses
Student 1: Yes	
Teacher: Mmm, yes?	Reconstructive paraphrase or recap

Based on the detailed coding procedures, the findings are presented as graphs of the time used on the different questions and responses shown as a percentage of total time. We also illustrate the findings using excerpts that represent typical examples of the different questions and responses shown in the graphs.

5.6 Teacher Questions in the Classroom

A large amount of time is spent on whole class teaching and teacher questions in both science and language arts classrooms; however, the teachers in language arts spend less time on whole class teaching compared to science classrooms (Ødegaard and Klette 2012). Language arts lessons usually begin with a whole class teaching sequence for the first 20 to 30 min, where the class talks about, and around, the different types of texts the students are reading. These include fiction and non-fiction, as well as poems, newspapers, articles, and various other materials. In the observed science lessons, a lot of the time is devoted to teacher-led whole class teaching, like checking the students' understandings of an ecosystem,

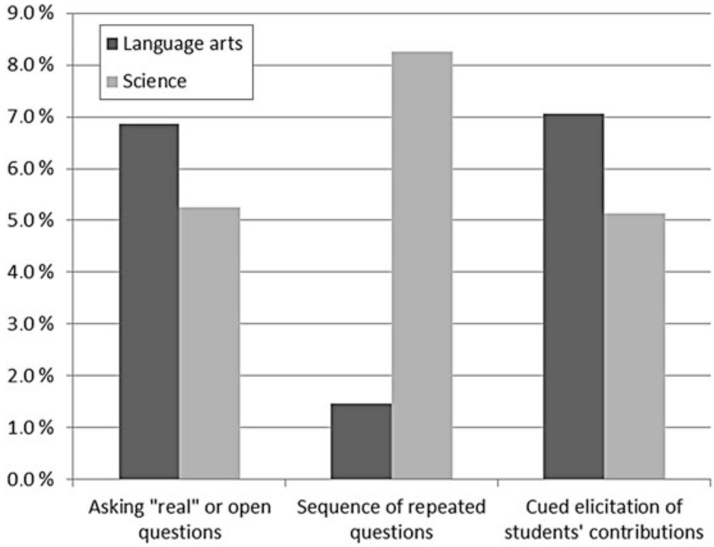

Fig. 5.1 Percentage of time spent on different types of teacher questions during whole class instruction in science and language arts

summarising a visit to a farm, or discussing issues related to smoking and drugs as part of knowledge about the human body. Thus, teachers in both science and language arts classrooms spend a quite a lot time on question–answer sequences. However, the type of questions that the teachers ask varies between these two subjects. We distinguished between dialogic teacher questions (e.g. 'asking 'real' and open questions') and authoritative teacher questions (e.g. 'sequence of repeated questions' and 'cued elicitation of the students' contributions'). Figure 5.1 displays the percentage of time used on different types of teacher questions during whole class instruction in each of the subjects. In science the time used on whole class instruction is 219 min and in language arts it is 211 min.

As illustrated in the figure, the science teachers spend more time on sequences of repeated questions, while the language arts teachers spend more time on asking 'real' or open questions. The language arts teachers appear to spend more time on cued elicitations. However, this is mainly due to one of the lessons, where the teacher spent about six minutes on cued elicitations, while in the other nine lessons on average only one minute was spent on this particular code. Below, we explore in more detail how these types of questions are played out in the two subject areas.

5.6.1 Asking 'Real' or Open Questions

As shown in Fig. 5.1, the language arts teachers spend more time on 'asking 'real' or open questions' compared to their colleagues in the science classrooms. The following excerpt from a language arts classroom serves as a typical example of how this is played out in our material. In this excerpt, the language arts teacher wants to know about the students' reading habits and begins with an open question.

Excerpt 1

1. Teacher: What kind of books do you read? Let's take a round and hear what you read and why. What do you read?

(A student shows the teacher her book, 'Butterfly Effect', by the Norwegian author Pernille Rygg.)

2. Teacher: What is it about?
3. Student: It is a crime novel.
4. Teacher: Who of you has read a crime novel?
5. Student 2: Crime novel?
6. Teacher: Yes, most of you have read crime novels. Why do we read crime novels?
7. Student 3: I think it is exciting.

Here the teacher asks a question that evokes more than a 'yes' or 'no' response, and he continues this questioning pattern throughout the whole lesson. He starts with an open question that can be answered in several different ways, and he continues to ask open questions throughout this sequence. As we can see in line 2, the teacher accepts the answer from the student even though we might assume that the teacher was expecting an answer about the book's literary genre or storyline. The teacher probes the students' thinking, building on their answers, asking them for reasons why they read crime novels (line 6). This type of question–answer sequence is quite common in the language arts lessons devoted to literature and literary texts in our material. However, these discussions are seldom related explicitly to a specific concept or terminology (e.g. literary genres).

The next excerpt is from a science classroom. Here they are talking about drugs, specifically steroids. They have gone through a text that describes some of the side effects from using steroids, and one of the students says that he knows some people that use them.

Excerpt 2

1. Teacher: Do you think they know about the side effects?
2. Student: I know many people that take steroids, they are healthy.
3. Teacher: They haven't lost their hair? Do you know for how long they have used them?
4. Student: No.
5. Teacher: No, here it says that if one uses them for a short period of time, one would not notice the side effects, so this happens if you use them over a longer period of time. But do you think that they know that it is dangerous? Do you think that the people that use them know that it is dangerous?
6. Student: No, but you can get sick from eating bad food as well.
7. Teacher: But you see if you put a lot of steroids into your body, it does not matter how healthily you eat.

As we can see, the teacher starts out with an open question, which is directed to this one student who knows people that use steroids. When the student does not directly answer the teacher's question, he asks some other more specific, but still open questions. In line 5, he gives the students some more background information about the side effects, suggesting that one may not see these effects after only having used steroids for a short time. He then directs yet another open question to the student about whether he thinks that the steroid users are aware of the dangers of using steroids. As can be seen from both theses excerpts, the teachers are attentive to student perspectives by using open questions to explore the students' understanding and interpretation.

5.6.2 Sequence of Repeated Questions

The teachers in science classrooms spend far more time on repeated questions and are, to a large extent, searching for a specific answer. The excerpt below from a science classroom illustrates this. This lesson is about smoking and tobacco, and the class is discussing tobacco and the risk of getting cancer.

Excerpt 3

1. Teacher: A lot of people who die of cancer, where do they go?
2. Student: Before they die?
3. Teacher: Yes, before they go to Heaven, before they die. Where do these patients get treatment? At the hospital? Is there a special hospital in our city that has a lot of people sick with cancer, which specialises in cancer treatments?
4. Students: Yes.
5. Teacher: And the name is? Just say "Rikshospitalet" as that is what it is called now, but it is a subdivision to the "Rikshospital" that is called ....?
6. Student: Cancer ward.
7. Teacher: Well – that would be the one . . . the cancer hospital has a name that is connected with something, they get radiated with something, and then they use raaa, raad.
8. Student: The Radium hospital.
9. Teacher: Yes, the Radium hospital.

In this sequence, the teacher is searching for a particular answer – the Radium hospital – and tries to ask the same question in many different ways to get the students to give the name of the institution. When the teacher is asking this type of questions, the students' contribution to the discussion is not followed-up by the teacher, but rather overlooked in the teacher's search for this very specific answer. The teacher starts out with an open question in line 1, but is after something very specific and the student who responds in line 2 does not seem to perceive this. In line 6, one of the students answers "cancer ward", which is an accurate proposal that is not, however, taken up by the teacher. The teacher has something else in mind and continues the questioning in an effort to get the students to understand the exact hospital he is searching for. In this question pattern, there is a lack of progress in the discussion, since the teacher's focus is on his predefined answer (e.g. the name of the hospital) rather than the proposals and ideas the students bring to the discussion.

The next, very short excerpt is also from a science lesson, in which the class has been on a farm visit the previous week, and the teacher wants to check what they have learned from this visit.

Excerpt 4

1. Teacher: Do you remember the definition of organic farming, what characterises organic farming? What was so special about that?
2. Student: It was better and it was not as polluting.
3. Teacher: I am thinking like very specific, what it takes for us to call it organic farming?

In this sequence, coded as a 'sequence of repeated questions', the teacher starts out with a question that can be answered in different ways; there is more than one right answer and/or proposal that characterise organic farming. However, the teacher in this excerpt has something particular in mind, and is not satisfied with the answer she gets from the student. Thus, she asks once again, but with a more targeted question to get the answer she is looking for. The teacher is not expanding on the students' ideas nor is she pursuing their answers or comments, such as the one proposed in line 2: "It was better and it was not as polluting." As can be seen from both these illustrations, sequences of repeated questions are used when the teacher is searching for a predefined, and often rather narrow, answer.

5.6.3 Cued Elicitation of Students' Contributions

When we consider questions leading to cued elicitation, the two subjects are more alike. The science teachers, however, invest more time on 'cued elicitation of students' contributions' compared to their language arts colleagues. The science teachers seem to help their students to arrive at 'the right answer' by giving cues to where the teacher is heading. A typical example is seen in one science classroom discussion devoted to smoking.

Excerpt 5

1. Teacher: If you think about the whole school, how many do you think smoke?
2. Student: Twenty per cent.
3. Teacher: Don't say it in per cent, I want it in numbers. There are about four hundred and thirty students in this school, and how many do you think are smoking?
4. Student: One-hundred and sixty-three.
5. Teacher: How many have you seen smoking then? Really seen?
6. Student: One.

When asking questions coded as 'cued elicitation of students' contributions', the teacher is giving the students cues to guide them in the direction the teacher wants the conversation to go. As shown in line 3, the teacher is not satisfied with the answer the student gives, so he tries to make the question more specific to give the student a hint about the answer he wants. In this excerpt, too, the teacher begins with an open question. However, when he does not get the answer he is seeking, the teacher continues with a cued questioning form. One can assume that he wants the students to think about the question a little longer before answering to get a more likely and/or correct answer. As we can see, the student first answers 20 %, and then suggests 163 students, which is approximately 40 %, and finally, after the teacher asks how many people the student has actually seen smoking, the answer is one. The teacher continues this conversation, however, by asking some of the other students how many students they have seen smoking and the highest number given is four. By insisting on the number of smokers – "Don't say it in per cent, I want it in numbers" (line 3) – the teacher uses cued elicitation to get the students to look beyond a percentage and realize how many of their school mates might actually smoke.

Thus far, we have discussed the teachers' use of questions. We now turn to how teachers respond to student utterances and questions during whole class sessions, including utterances based on the teachers' questions.

5.7 Teacher Responses to Students' Utterances

In our analysis of teachers' responses to students' contributions, we distinguished between 'revoicing or reflecting students responses'; 'providing neutral responses to students'; 'reconstructive paraphrase or recap'; and 'providing evaluative responses'. The differences in teacher responses between science and language arts lessons are more subtle than the differences in the way the teachers ask questions. The two response types that differ the most between the two subjects are 'revoicing or reflecting students responses' and 'reconstructive paraphrase or recap' In the case of the response types 'providing neutral responses to students' and 'providing evaluative responses 'the two subjects show a similar response pattern. Figure 5.2 summarises the percentage of time used on the different types of teacher responses in the classrooms analysed.

Below, we elaborate on and illustrate the teachers' use of 'revoicing/reflecting student responses', 'providing neutral responses to students', 'providing evaluative responses', and 'reconstructive paraphrase or recap' in responding to student utterances.

5.7.1 Revoicing or Reflecting Student Responses

'Revoicing or reflecting student responses' is the most frequently used response to the students in both science and language arts classrooms. However, the science teachers invest more time than their language arts colleagues on 'revoicing or reflecting student responses'. The excerpt below is an illustration from a science classroom. This example is from the same lesson as Excerpt 4, where the class discusses their experiences after a visit to a farm.

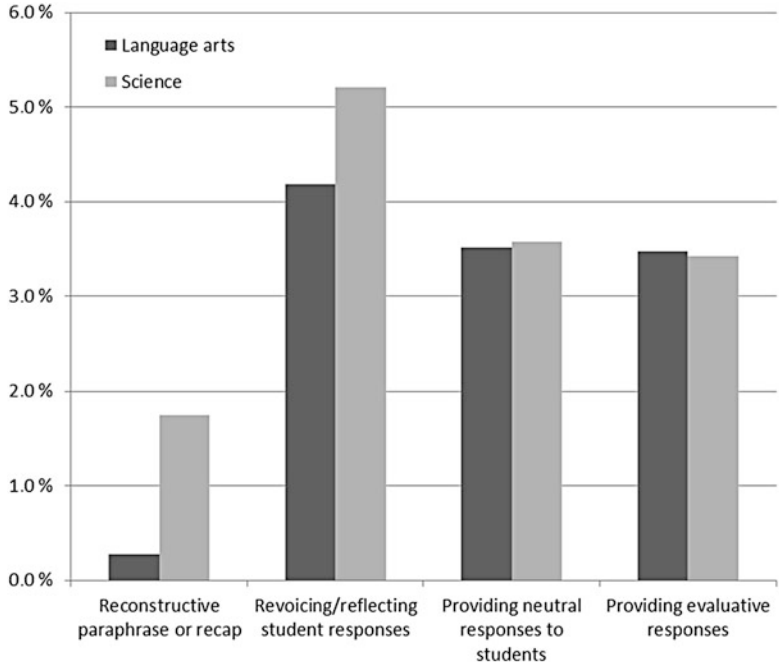

Fig. 5.2 Percentage of time spent on different types of teacher responses during whole class instruction in science and language arts

Excerpt 6

1. Teacher: Is it something that you would like to bring up?
2. Student: The care of the animals.
3. Teacher: The animals, care of the animals, mmm. Yes.
4. Student: Harvesting.
5. Teacher: Harvesting. Is it the flax you thought about then or other things as well?
6. Student: Both.
7. Teacher: Both yes.

When a teacher is revoicing or reflecting on a student's response, he or she repeats what the student has said without changing or altering the meaning of the statement. As we can see from this excerpt, the teacher is revoicing the students' contributions for every new answer she gets. Sometimes the teacher revoices or repeats the student's statement in a question-style format to clarify what the student means, such as in line 5 where she wants to determine exactly what the student was thinking about. Or she simply repeats verbatim what the student has said, as shown in lines 3 and 7. However, the teacher also confirms that the students' answers are correct, so she is not only revoicing the students, but also providing evaluative responses.

5.7.2 Providing Neutral Responses to Students

Another frequent teacher response is 'providing neutral responses to students'. The science and language arts teachers in our analysis spent about the same amount of time on this response. When providing a neutral response the teacher repeats the students' comments or provides a comment that does not suggest whether the students' statements are correct or incorrect. The first excerpt below is from a language arts lesson, where the students are discussing a text they have read in preparation for a visit from the author of the text.

Excerpt 7

1. Teacher: Do boys talk together about love stuff and girls?
2. Student: Yes.
3. Teacher: Ok, they do, but do they talk about everything then, like that girls are a little bit weird and so on, as he says here or? (Refers to the text)
4. Student: In a way.
5. Teacher: In a way they do.

Here the teacher starts with an open question and after a short "yes" from the student, she elaborates on the student's answer by referring to the text. In the last line, the teacher revoices the student's answer.

This next excerpt is from a science lesson, involving the same teacher as in Excerpt 5, but from a different lesson. They are still discussing tobacco and smoking.

Excerpt 8

1. Student: Are there many tobacco factories in Norway?
2. Teacher: That is a clever question because at least we have Tiedemann's Tobacco factory; it is the one with the fox, and I think it just closed. I assume that tobacco factories still exist in Norway; in general, I think they get the tobacco plant delivered from other places, but they make the brands and mix the tobacco here and what they put in it one can only imagine.

This sequence starts with a question from a student, and the teacher replies to the question by providing a comment. The teacher's response does not indicate whether the student's question is valid or invalid, since the teacher only gives the student a neutral response to the question that is asked.

5.7.3 Providing Evaluative Responses

The response type 'providing evaluative responses' is used to the same extent in science and language arts classrooms, and for the same amount of time as the previous response in both subjects. When the teacher provides evaluative responses to students, they can both confirm and refute what the students have said. The following excerpt is from a language arts lesson, which focused on how to write a text.

Excerpt 9

1. Teacher: What is it that all texts, no matter if you write a story or a chronicle, as you did in the spring or another type of text – what is it that all texts consist of, what parts do we find in all texts?
2. Student: Introduction, body, and conclusion.
3. Teacher: Yes, those are the large parts, and we know that it involves either our imagination as in the case of a story, or our thoughts and opinions, as in the case of a chronicle, an argumentative text. Whatever we try to write about, we have to divide our thoughts a bit .... We also divide it into some larger parts, as in this text. What do we call that?
4. Student: Sections.
5. Teacher: Sections and this is important.

As shown in line 3, the teacher provides the students with a confirmative response, but she also clearly searches for another answer that is more specific. The teacher receives the answer she is looking for in line 4, namely “sections”, and in line 5 the teacher revoices the student, but also clearly indicates that this is correct by underscoring that it is important.

5.7.4 Reconstructive Paraphrase or Recap

As shown in Fig. 5.2, ‘reconstructive paraphrase or recap’ is the least used response type to students’ utterances in both the science and language arts classrooms. However, this response is more common in the science classrooms than in the language arts classrooms. The following excerpt from a science lesson, talking about the ecosystem, may illustrate this:

Excerpt 10

1. Teacher: Can anyone give me an example of things that are not alive that are of significance for the ecosystem?
2. Student 1: Soil.
3. Teacher: Soil, yes! I will write topsoil as that is what we often call it. Yes?
4. Student 2: Water.
5. Teacher: Ok, should we say landscape? Then it covers whether it is by the water, a mountain peak, a valley, in a sunny side and so on. Landscape embraces much more.
6. Teacher: Anyone else have an example?
7. Student 3: Air.
8. Teacher: Yes, should we say climate, since it is about the air around?

In this response pattern the teacher alters the original statement of the student to a more acceptable form and preferred language. This most commonly occurs when the teacher is asking for something, but has already decided the kind of answer that he or she wants. As we can see, the teacher is asking the students open questions;

however, she is not satisfied with the students' answers, and alters them into her preferred language and conceptual format.

In summary, there is a difference between science and language arts teachers in the way that they ask questions, but the difference between the subjects is not as distinct when we analyse how teachers respond to students' answers.

5.8 Discussion

The basic purpose of these analyses has been to investigate if there is a difference in the way that teachers ask questions and give responses to students between the two, rather different, school subjects of science and language arts. As summarised in the theory section above, teachers use questions as one of their most frequent instructional tools, despite the fact that questions can serve different functions and purposes. We were interested in the role of 'dialogic' and 'authoritative' questions and responses in the two subject areas and possible patterns and differences. Our analyses indicate that a great deal of time is spent on question–answer exchanges in both subject areas; however, these exchanges differ between the two subjects, especially with regard to patterns of teacher questioning.

The findings suggest that the language arts teachers spend more time on asking 'real' or open questions than their science colleagues. The science teachers, on the other hand, spend more time on sequences of repeated questions; this can indicate that the science teachers are more concerned with getting a correct answer from the students. In both subjects the teachers in our analysis spent quite a lot of time on cued elicitations; however, in language arts this result is largely dependent on one lesson where the teacher spent six minutes on this code, compared to the average of one minute in the other nine lessons. In science the time spend on cued elicitations was more equally divided between the lessons.

Like Mortimer and Scott (2003) and Furtak and Shavelson (2009), we argue that questions asked in a more authoritative way can be of great importance to students' learning. As such, the dilemma is *how* teachers combine these different question types in order to involve the students in the classroom conversation, rather than privileging one specific question style. Teachers need to use questions to test students' understanding, as well as to involve the students in the classroom conversation and/or focus on or emphasise a particular phenomenon. We will argue that teacher questions serve many purposes, and teachers need all question types in their toolkit when trying to stimulate discourse, engagement and participation in classroom conversations. With this in mind, we discuss our findings in more detail below.

As shown in the theory section, one of the reasons why more time is spent on asking open questions in the language arts classrooms may be that the teachers are working with a lot of different types of texts and text genres as a main topic in these classrooms. This provides an opportunity for competing interpretations, which introduce different perspectives and views, including personal impressions and interpretations of the text. The working methods of science, i.e. the nature of science and inquiry, however, stress critical reflection and argumentation, although it may seem that the teachers in science classrooms are more focused on checking the students' knowledge and asking for specific conceptual terms. Osborne and Patterson (2011) stress the importance of students being able to separate between explanation and argumentation, and claim that students are often not trained in this as part of their science education. One of the reasons, they argue, may be that the construction of knowledge is given priority over the costs of argumentation and critical reflection. Another reason for less time being spent on asking 'real' or open questions in the science classrooms might be the topic covered; the topics covered in our data were 'the ecosystem', 'smoking, drugs and the human body' and 'pollution/organic farming', all themes which require factual knowledge and which might provide less opportunity for interpretation and personal thoughts. It is not possible for us to establish whether our science teachers are restricted by the textbooks or the existing teaching traditions. However, one could assume that they are influenced by both; and, this would also apply to the language arts teachers who tend to ask more open questions.

This argument is also corroborated with findings from one lesson in language arts that had grammar as a topic. This lesson had fewer open questions and more of an authoritative questioning pattern; hence, the differences between science and language arts may be linked to the topics that are being taught and discussed, as well as differences in teaching traditions. The language arts lessons in Norway have a tradition of emphasising students' interpretations of text and text genres in this subject. The PISA results from Norway in reading, for example, show that the students (and especially girls) do well in reading assignments when they are asked to interpret and think about the meaning of the text, especially for fiction and literary texts (Roe 2010).

This is not necessarily the case in science. In the results from the science tests in the PISA 2006 survey, three different competency areas were emphasised, the third of which was 'to be able to use scientific evidence'. Norwegian students clearly lacked competence in scientific argumentation. This may be linked to the fact that their science teachers ask quite a lot of closed questions that require a specific, predetermined answer, so that students do not have an opportunity to develop their own reasoning and to actually test out their thoughts using scientific evidence (Kjærnsli et al. 2007). This is also in line with Osborne and Patterson's (2011) argument that the construction of knowledge seems to be given priority over the value of learning to argue.

According to Alexander (2008), students are frequently encouraged to provide extended answers. Alexander also argues that these answers are seldom responded to in a way that helps the students to move forward in their learning. In our study, the teachers' responses to the students were to a large extent dialogical, meaning that they either 'reflected or revoiced the students answers', and/or provided them with 'neutral responses'. The response type 'reconstructive paraphrase or recap' was seldom used by our teachers. Scholars agree that, in order to be productive for students' learning, teachers' responses should build and/or elaborate on the students' answers, and not only evaluate the students' answers by restating and/or revoicing their arguments. Teachers' careful use of reconstructive paraphrase in combination with their capacity to explain why something is right or wrong, can provide competing perspectives and voices. This kind of teacher response has proven to stimulate student engagement and student participation during whole class conversations (Alexander 2000; Alpert 1987; Emanuelsson and Sahlström 2008; Nystrand et al. 1997; Stein et al. 2007). These teachers are not simply accepting the answer from the students, thereby putting a possible dialogue to rest; rather, they engage with the students around the answer and prolong the possible dialogue (Juzwik et al. 2008).

Our analyses indicate that teachers' responses during whole class discussion are, to a fairly large extent, dialogic, thus providing opportunities for dialogue and student engagement. A side effect of this may be that student participation in dialogues reduces their ability to acquire the content matter involved, thus privileging participation (Emanuelsson and Sahlström 2008) over academic clarification. Chin (2007) argues that teachers who focus more on dialogue want to find out what students think, and encourage them to elaborate on their previous answers and ideas.

5.9 Conclusions

Our results indicate that there is a difference in the way teachers question students between the two subjects of science and language arts. These differences may be due to a range of reasons, as we have proposed in our discussion. One of the reasons may be the different teaching traditions between these two subject areas as school subjects. On the other hand, it may be that the topics discussed in these lessons were quite different – the language arts topics were more open to interpretation, and the topics in the science lessons were more factual. However, this might be a little simplistic. It is most likely that a combination of the teaching tradition of the subjects and the topic in focus regulates the type of conversations and teacher questions in these subject lessons. These differences might appear in this way in this study because we have analysed whole class teaching, and they might present differently in an analysis of individual and/or group work. It may also be that these differences become more distinct during whole class sessions, and might not be as prominent during other instructional formats such as individual seatwork and group work.

As we have discussed in this chapter, questions can be used in a range of different ways and for different purposes. Most important for teachers to consider, however, is how to make use of the different questions and responses in order to facilitate students' classroom participation and contribute to student learning.

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Chapter 6
Students' Perspectives on Reading Instruction and Reading Engagement

Astrid Roe

6.1 Introduction

Good reading skills are a prerequisite for success in education, at work and in everyday life, Moreover, reading engagement and good reading strategies are key factors in achieving such skills. Reading engagement certainly has an immediate influence on students´ reading ability, and it might predict to what extent students will read in the future, and thus influence their learning success in life. Data from the National Assessment of Educational Progress (NAEP) in the United States shows that adolescents who identified themselves as being interested in reading achieved better scores on the tests, and they had better high school averages than students who were less interested in reading (Donahue et al. 2003).

International surveys like PIRLS (Principle Investigators and Research Leaders Survey) and PISA have provided strong evidence for the benefits of engaged reading, which has consistently been found to be a critical variable in reading achievement. PISA 2000 showed that the level of reading engagement had the largest median correlation with achievement, exceeding even the median correlation between reading literacy and socio-economic status (Kirsch et al. 2002). In PISA 2009, students' knowledge and awareness of reading strategies were also measured. Students were asked to evaluate the extent to which a range of strategies are useful for learning and remembering information in texts. Students whose evaluations of the strategies matched those of experts had considerably higher levels of reading performance than those who were less familiar with or uncertain about the usefulness of these strategies. These results suggest that school can play a significant role in bridging the gap between advantaged and disadvantaged students, by acting

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as strong clear determinant of students' levels of reading engagement and reading strategies (OECD 2009, p. 61).

Quantitative studies can investigate students' reading achievement, attitudes towards reading and awareness of reading strategies by means of standardized tests and questionnaires. Such studies serve the purpose of yielding results that can be generalized to larger populations. In order to get a better insight into what actually takes place in the classroom, and to give more in-depth knowledge about selected groups of students, there is a need for qualitative research methods like classroom observation and interviews. In the present study, interviews have been used to investigate students' experiences in terms of their teachers' role as a contributor to their reading engagement and their knowledge and awareness of reading strategies.

6.2 The Importance of Reading Engagement and Reading Strategies

Reading engagement encompasses motivation, cognitive interaction, and receptivity to the text. Engaged readers are interested in finding value in texts, and engagement is therefore equally as important as cognition in the process of reading (Guthrie and Cox 2001; Pflaum and Bishop 2004). Reading engagement not only involves voluntary reading for pleasure and positive attitudes towards reading, it also includes the commitment and perseverance that committed readers mobilize in order to read challenging or complex texts necessary to obtain a personal advantage or a specific goal, for example to pass an exam or to obtain certain civil rights. Furthermore, it is essential for the maintenance and further development of reading skills beyond school. The teacher's role as a motivator of good reading habits and a contributor to students' reading motivation should therefore not be underestimated. By contrast, teachers who neglect these instructional practices undermine students' efforts to become self-directing, resulting in students who are disengaged from reading and fail to progress in reading achievement (Guthrie 2008).

Reading strategies are what effective readers do to understand and learn from written texts. In other words, effective readers are strategic readers. In using effective strategies, the reader interacts with the text by conceiving reading as a problem-solving task that requires the use of strategic thinking, and by thinking strategically about solving reading comprehension problems. When readers are strategic and reflective about their thinking and learning, they are said to be utilizing metacognition skills, and in connection with reading the term *metacomprehension* can be used (Gavelek and Raphael 1985, pp. 22–23; Osman and Hannafin 1992; Caverly et al. 1995). Several studies have found an association between reading proficiency and metacognitive reading skills (Artelt et al. 2001; Brown et al. 2004).

In the teaching of good reading strategies explicitness is a key factor. Explicit or formal instruction of reading strategies is believed to lead to improvement in textual understanding, and there are indications that explicit reading instruction has positive effects on students' achievement. Researchers have concluded that a structured, explicit, and scaffolded approach to instruction has a positive impact on students' academic achievement (i.e. Roseshine and Stevens 1986; Good and Brophy 2008). Moreover, Mackeya et al. (2007) found that students' perceptions and teachers' intentions about the linguistic target of corrective feedback overlapped the most when feedback was provided explicitly. The underlying principles of effective instruction that have emerged from educational research conducted over the past 30 years can be viewed as the basis of effective, explicit instruction, while the elements of explicit instruction can be seen as methods to ensure that these principles are addressed in designing and delivering instruction (Archer and Hughes 2011, p. 64).

6.3 The Interviews

6.3.1 The Selection of Students/Research Method

The 42 students who were interviewed in the present study were in their second year of lower secondary school and represented the six schools where the video study described in Chap. 2 was carried out, plus one additional school. The students' language arts teachers were asked to select three girls and three boys representing low, middle and high reading proficiency. Due to the unforeseen absence of two girls, who were replaced by two boys at one school, 22 boys and 20 girls were interviewed. A semi-structured interview protocol was used, and the total length of each interview was 15–20 min, depending on how much the student was willing to elaborate on each topic. Most of the interviews took place just after one of the language arts lessons that were video recorded, and if it was relevant, parts of the interviews were related to what had happened during that lesson.

The first part of the interview includes questions about reading engagement and reading habits and attitudes towards reading. This chapter presents the second part of the interview, which focuses on the teacher's role as a reading teacher, the students' use of reading strategies, and the students' views on difficulties in their text books. The students were asked the following questions:

- What have your teachers done to encourage you to read in your leisure time?
- What kind of reading instruction have you received in lower secondary school?
- What kind of reading strategies do you use, for example, if you have problems understanding the meaning of a text?
- Do you find the textbooks in any subject more difficult to read than the textbooks in other subjects?
- Is it important to be a good reader?

For each question they were encouraged to elaborate and give as many examples as possible. The interviews were tape recorded and transcribed.

The transcribed material was systematized and organized in relation to the thematic content of the students' responses. As there turned out to be no obvious or significant differences between students from different schools, or with different proficiency levels in reading, the results will mainly be presented in terms of the percentage of students in the various response categories, for example, the percentage distribution of the various subjects that students found difficult. If the number of students in a response category is just one or two, the exact number is given. Examples of representative or interesting responses will be quoted to illustrate the findings. For some topics gender issues are interesting and will be reported and discussed.

6.3.2 The Teacher's Role in Promoting students' Reading Interests

The students spoke quite clearly and confidently about their teachers when discussing encouragement or inspiration to read in their leisure time. The students very clearly positioned themselves in four response categories and Table 6.1 shows the percentage of students in each of these categories. Only 5 % of them (two students) gave spontaneous positive answers about their present teachers, whereas nearly one-third of the students felt that their current teacher's attempts to inspire them often had a negative effect. Half of the students said that their current teachers had no effect on their reading interests. 17 % (seven students) referred positively to their primary school teacher.

One girl rather ironically put it like this: "Oh yes, the teacher sometimes comes up with stupid suggestions about boring books that we should read". Others explained that the teachers' suggestions in terms of reading activities always sounded like boring duties or school tasks that they were obliged to do, and consequently they had no desire to do them. In one of the classes the students had just worked with a reading project, and when reminded of this, one of the girls said:

> Oh yes, we had this reading project, but that did not really inspire me very much. It was like: Oh, I have to read a book and then write a summary of the book. And that is rather boring. Like, when the teachers say: You have to read this book within two weeks, and on Friday you must hand in an essay or a review about the book. And they give us 1000 questions about the book that we have to answer. That is reading on the command. I never do that when I read a Harry Potter book at home. I never write a little book review all by myself, voluntarily. I just read – or I don't.

Table 6.1 Teachers' effect on students' reading engagement (N = 42)

Positive effect	5 %
Negative effect	29 %
Only the primary school teacher had positive effect	17 %
No effect	49 %

The most positive students referred to teachers who encouraged them to read to become better readers – or in most cases – better writers:

> The teacher says we should read to become good writers, because we learn from good authors. And I also believe that we create images inside our heads during reading, and thus we learn how other people think and what they are like and so on.

One boy in the category "No effect" said that a male author who had visited his school had been really inspiring to listen to, and that he had actually gone to the library to borrow some of his books straight away. With regard to the teachers, the same boy put it like this: "The teachers never tell us why it is important to read, they just say that we should read."

Although the teachers referred to by these students will certainly have tried to encourage them to read, the students' responses suggest that teachers do not have the same status as a role model in secondary as in primary schools. Their rather negative responses may also be an expression of teenagers' reluctance to credit their teachers with having influenced their attitudes and interests positively. Selective memory or the fact that they simply have not been listening may also explain these results.

6.3.3 Reading Instruction: What Is That?

When the students were asked what kind of reading instruction they had received in lower secondary school, the vast majority of them expressed confusion and seemed to have problems understanding the question. Some misinterpreted the question and thought reading instruction had to do with decoding of letters like the first reading instructions they received in primary school. Others started to talk about fluency when reading aloud, and some thought it meant special instruction for students with reading difficulties, for example, dyslexia. In other words, for many of these students, the term 'reading instruction', meaning 'reading strategies instruction', seemed not to be part of their consciousness or field of knowledge.

After having cleared up these misconceptions, by explaining that we were going to talk about reading instruction in terms of reading comprehension strategies, it turned out that 67 % (28 students) still gave negative answers like

- *No I haven't*
- *I don't think so*
- *I cannot remember*
- *I still don't know what it is*

Among these 28 students, six eventually remembered that their primary school teachers had talked about reading strategies, but their present teachers had not. Two of them held that they had only learnt reading strategies at home, and one student mentioned that her English teacher had taught them reading strategies in English as a foreign language. Still, 46 % of the students were not able to recall any kind of reading instruction, except for early beginner instruction (Table 6.2).

Table 6.2 Reading comprehension instruction in secondary school language arts lessons (N = 42)

No reading instruction except for beginner instruction	46 %
Some reading instruction, one example from each student	33 %
Only reading instruction in primary school, in foreign language lessons or at home	21 %

One of the girls who said that she did not know what reading instruction was had just attended a language arts lesson where the teacher had addressed specific literary techniques that the author of an argumentative text had used in order to promote his views. She was reminded of this, and asked if she thought such knowledge could help her understand the meaning of the text better. She replied: "I don't know, I did not think of it as reading instruction, I thought of it as language arts, but of course, such knowledge may influence my writing skills positively."

Knowledge of how texts are built up, the author's use of literary techniques, genre features, writing style, etc., are embedded in good reading strategies, and can undoubtedly help students understand the meaning and intention of a text (Mc Laughlin and Allen 2002; Duke and Og Pearson 2002). If the teacher had stated explicitly how knowledge about the textual features can contribute to better understanding of the text, the students would probably have recognized it as reading instruction.

One-third of the students reported that they had been given reading instruction in lower secondary school, but none of them gave more than one example:

- *Writing key words (3 students)*
- *Doing written strategy exercises in exercise booklets (1 student)*
- *Study the headings in the text books to get an overview of the content (2 students)*
- *Skimming the text to quickly get an impression of what it is about (3 students)*
- *Writing reading logs after reading fiction (2 students)*
- *Reading slowly to avoid missing important details (1 student)*
- *Regularly stop and think about what one has read (1 student)*

The students were asked what strategies they used to understand what they read, especially when they were supposed to learn something from it. These were the two most common responses:

- *I read the difficult passage over again*
- *I ask someone (teachers, peers or family members) to explain difficult words and/or sentences.*

The majority of the strategies mentioned by these students represent only a narrow selection of what are considered essential strategies by leading reading researchers. For example, the strategies promoted in reciprocal teaching (Palincsar and Brown 1984): summarizing, questioning, clarifying and predicting, and the four categories of strategies mentioned by Anmarkrud in Chap. 3: memorization, elaboration, organization and monitoring. Studying headings or skimming through the text to preview it, which was mentioned by a total of five students (12 %), can be defined as *predicting*. Likewise, the following comment, mentioned by one student, can be categorized as summarizing: "I regularly stop and think about what I have read".

The 44 language arts lessons that were videotaped show several sequences where teachers discuss the content of texts with the students, for example, by relating it to other texts or to the students' personal knowledge or experiences. The teachers also frequently ask questions about the content or formal features of the texts. This is in line with good reading instruction, and teachers who do this is discussed by Anmarkrud in Chap. 3. However, none of the interviewed students mentioned these dialogues or situations when we talked about reading instruction. As long as students do not perceive this form of teaching as reading instruction it is highly uncertain whether it has any direct effect. Knowledge of the text is always an advantage, but the instruction has probably not been explicitly related to reading comprehension.

6.4 Metacognitive Awareness

The majority of the interviewed students admitted that they often thought about something else when reading texts that did not engage them, which is not surprising. A common problem during reading is that one's mind may wander onto something else midway through the page. Conscious readers discover quickly that their minds have wandered and are able to take relevant action, which means they have well developed metacognitive awareness. When asked what they did if they found themselves thinking about something else during reading, most of the students said that they started over again. However, many of them admitted that reading the passage twice or even three times did not always help. 24 % of the students (eight boys and two girls) said that they did not mind, because even if they re-read the passage several times, the content was either so boring or complicated that they still couldn't concentrate. The following dialog with one of these boys is representative of these students:

I: What do you do if you don't understand what you are reading?
S: Sometimes I read, and at the same time I think about something else, then I haven't understood.
I How far can you read before you become aware of that?
S: Sometimes it can take long.
I: What do you do when you realise that you have been thinking of something else?
S: (laughs) I close the book and conclude that I have read it.

These students seem to consider school reading as a task which is finished when it is done, regardless of what they have learnt from it. This fits with the findings of researchers who claim that adolescents' reading problems may be caused by problems with the interpretation of the contents rather than with the decoding of words.

And in many cases they are probably caused by lack of concentration and attention. Mechanical and unconscious reading may thus explain why students with no diagnosed reading difficulties perform poorly on reading tests (i.e. Catts et al. 2005).

6.4.1 Easy and Difficult = Fun and Boring?

The students were asked if they found any of the text books or other school-related reading material particularly difficult to read. One-third of the students could not think of any particular subject, but those who did mentioned Science (14), Language Arts (6), History or Social Science (6) or Religion and Ethics (5). These subjects are generally heavily text based and include quite a lot of reading, and the texts involved may be demanding in terms of advanced vocabulary and complicated sentence structures. One striking finding was that nearly two-thirds of the students who mentioned a certain subject, changed the wording in their answers from "easy" or "difficult" to "fun/interesting" or "boring". The following two examples are representative illustrations of their answers:

> Well, it depends, it has to be interesting. You must want to read it. Most subjects become interesting if you force yourself to read and understand it. If I don't care, it becomes rather boring. I find science pretty tiresome. There are so many strange words, and the content is sometimes hard to understand. If the teacher has not gone through it properly with us, I really have to concentrate, and I have to read it again and again until I understand – and then all of a sudden I sometimes become interested.
>
> Yes, I have noticed that if we have been working with something extremely boring in Science, like you just sit and read, but you have no interest whatsoever in learning it, then you don't get it, and you have to read it again and again, and it becomes more and more boring … but in social science, we have been learning about law and order, and that has been very interesting, because we have not had anything about it before, And then everything sits in your head after having read it once.
>
> … Come to think of it … the science books are quite easy to read …

Interest and commitment obviously play a major role in reading comprehension. Many of the students also mentioned other factors that characterized texts that they considered difficult – or boring – as most of them put it:

- *compact with a lot of information*
- *texts too long – too much to read*
- *small fonts*
- *complicated charts, tables and graphs*
- *old-fashioned language*
- *advanced language*
- *formulas and scientific language*
- *difficult words*

These may be characteristics of texts that are apparently difficult, and thus, apparently boring. Nevertheless, these are texts that students will encounter more and more often in their further education and working life.

6.5 The Importance of Being a Good Reader

Finally the students were asked what reading meant to them personally and whether they thought it was important to be a good reader. Almost all of them admitted that reading is important.

I: Why is it important to be a good reader?
S: Because you have to, you read all the time, it is something you need out there (. . .) there are signs and maps and. – well – when you start upper secondary school, you have to be able to read and understand what you read, so . . . Even if we have advanced technology, I don't think anyone can read for you, and then you just understand somehow. They invent more and more all the time, so you have to read more and more to get to know what they have found out, so . . .

Thirty-six percent of the students related the importance of being a good reader to becoming a better writer. Some of them also mentioned language-related factors like improving their knowledge of grammar and academic terminology. Thirty-one percent focused on the personal and intellectual development that reading supports and the importance of learning something new. Fourteen percent mentioned technical reading skills. One reason why so many students mentioned writing skills is probably the strong emphasis on writing instruction in Norwegian schools. Writing instruction does not end when the students have learnt the basic writing skills, and most secondary school teachers of language arts give students explicit writing instruction regularly. Special attention was paid to writing instruction in secondary schools after the successful introduction of "Process Writing" in the late eighties. A large study of Norwegian 10th graders' writing skills concludes that Norwegian students are good writers (Berge et al. 2005).

6.6 Summary

The 42 students who were interviewed represented an equal distribution of readers with low, middle and high levels of reading proficiency; however, these three levels of reading proficiency were hardly reflected in the interviews. This may of course be due to the fact that the number of students in each group was so low that it is difficult to conclude that there are significant differences between them. Even so, there was no clear tendency for weak readers to speak less positively about reading than good readers. Although the best readers probably had better reading strategies than the poor and average ones, they were not able to express their knowledge better or use of it more explicitly than the others. With some few exceptions, no obvious gender differences appeared in this part of the interview.

The most discouraging finding was that the students had few positive things to say about their teachers as sources of inspiration or as motivators. Further, only one-third of these students could remember having received any kind of reading instruction in secondary school.

The majority of them had no clear idea of what reading strategies were, and there was a widespread perception among these students that reading instruction was the same thing as beginner-reading instruction or special education. Their explicit repertoire of reading strategies was rather narrow. Those who mentioned specific reading strategies that they used referred to techniques such as skimming and scanning the text, or writing key words.

When asked about easy or difficult texts, many of the students changed the wording to “fun” and “boring” texts. A positive aspect of the students’ responses was that almost all of them believed that reading skills are important, not only at school, but also throughout life.

The results of these interviews may seem rather discouraging in the light of what constitutes good reading instruction in the research literature (i.e. Pressley 2002). However, one must bear in mind that interviews such as these do not give a complete picture of what has been going on in the students’ classrooms. Moreover, students may give selective answers, or they may not always remember what the teacher has said or done. And last but not least, the intended teaching is not always in accordance with perceived student learning (Goodlad 1979).

It must also be added that these interviews took place before the school reform that introduced reading as one of five basic skills across the curriculum, and which has led to a much stronger emphasis on reading engagement and reading instruction in schools than before the reform (Hertzberg 2011). However, previous research has shown that school reforms, on their own, are not always enough to change teaching practice.

6.7 Implications for Practice

The encouragement to read and the explicit reading instruction that students receive throughout the first years of schooling are no doubt crucial for their future development as readers, but further follow-up at upper primary and lower secondary level is thought to be equally important However, until recently research has shown that reading instruction more or less ends after 4th grade, and that secondary school teachers’ knowledge of what has been referred to as reading instruction and teaching of reading comprehension strategies varies a lot (Alvermann and Moore 1991; Pressley 2002).

The teacher’s role is undoubtedly important, because not all students come from homes where reading is valued and where someone is able to help struggling readers.

And maybe most important of all, reading instruction must not stop when students have learnt to read after the first school years. Teachers must continue to give explicit reading instruction throughout secondary school. Most secondary school teachers know a lot about good writing instruction, and most of this knowledge can be transferred into good and explicit reading instruction. Teachers also know that reading and writing are equally important, and they know how to develop students' writing skills. Now they need to be aware of the fact that students also need instruction to continuously develop their reading skills throughout school, and they need to learn how to teach good reading comprehension.

Reading takes on an increasingly prominent role in learning during middle and secondary school. There are strong indications that strategic and engaged readers provide themselves with self-generated learning opportunities that are equivalent to several years of education. Good reading skills may substantially compensate for low family income and poor educational background (Guthrie and Wigfield 2000, p. 404). The development of reading literacy involves not only the development of skills and knowledge, it also includes motivation, attitudes and behaviours (Guthrie 2008).

Interest in reading is facilitated by classroom and school contexts that emphasize the relevance of texts to the student's background knowledge and experience (Assor, Kaplan, and Roth 2002). When students read material that is directly related to their personal interests, their comprehension is higher than if their reading is driven by a desire for test scores only (Vansteenkiste et al. 2006). Likewise, texts rated as "interesting" are read more thoroughly than other texts (Schiefele 1999). Therefore it is imperative to find intriguing and catchy texts, especially for the weakest readers, and also to provide them with good reading strategies.

The teachers interviewed by Anmarkrud in Chap. 3 speak positively about the importance of being a good reader, and the way they speak about reading instruction indicates that their intentions are good. However, the interviews in the present study indicate that the degree of overlap between teachers' intentions and learners' perceptions is not always as expected. Furthermore, Anmarkrud and Bråten (2013), who also based their analyses on data from the video study, found that the teachers varied vastly with respect to the amount of comprehension strategies instruction they taught, that the repertoire of strategies taught was quite narrow, that the instruction was mainly implicit, and that the teachers lacked professional knowledge about reading comprehension and reading comprehension instruction. As reading engagement and motivation to learn seem to be mutually dependent on each other, the challenge is to translate them into viable classroom practice.

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Part II
Discourse Matters

Chapter 7
Talk and Use of Language in the Science Classroom: Characteristic Features

Marianne Ødegaard, Nina E. Arnesen, and Kirsti Klette

7.1 Introduction

Researchers in science education agree that learning science includes, and is also facilitated by, use of scientific language; learning to talk science (Lemke 1990; Mortimer and Scott 2003; Norris and Phillips 2003; Wellington and Osborne 2001. In addition, scientific language is an important part of the nature of science and should, as such, be included in the teaching of science. These two points about language and learning science ought to be reflected in the language used in science classrooms. In our study of lessons across the three subjects Science, Mathematics and Language Arts (Klette et al. 2008) and in a separate study of science lessons (Ødegaard and Arnesen 2010), we found that a large proportion of the science lessons, significantly larger than for the two other subjects, were characterized by teacher-led dialogues. Taking these findings as a point of departure we have analyzed the material from the science lessons we have studied to try to clarify the characteristics of classroom talk and use of language in science lessons.

In their systematic review of classroom dialogue covering the full range of compulsory schooling, Howe and Abedin (2013), found that much more is known about how classroom dialogue is organized than about whether certain modes of organization are more beneficial than others. They also found that more studies are concerned with patterns of participation than with content. Although, several of these studies involved scientific knowledge as content, only one study reported on

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the use of scientific terms (Ash 2008). Further, Howe and Abedin's review indicated that the greater part of classroom dialogues about science are small-group dialogues. We have found several recent examples of studies characterizing teacher-led science classroom dialogues (Aguiar et al. 2010; Almahrouqi and Scott 2012; Tan and Wong 2012), and they are all more concerned with communicative approaches than the language used. One ethnographic study focusing on language use and teaching reported on how a teacher synthesized vernacular and scientific language when teaching minority students in order to scaffold students' understanding (Brown and Spang 2007). Interestingly, they found that the students copied the teacher in synthesizing everyday and scientific language.

In this chapter we would like to contribute to knowledge about classroom dialogues by giving an overview of the content of talk and language use in teacher-led conversations in science. We believe that these whole class dialogues provide an important model for students and offer them language tools that enable them to talk about and thus understand science, if they are given opportunities to practice.

Our research question is: What characterizes talk and language use in teacher-led dialogues in the science classrooms we have studied in the PISA+ project?

7.2 Theoretical Perspectives for PISA+ Science

Learning is often portrayed as a meaning-making process, where ideas are shaped as they are expressed in language in a social context (Alexander 2000, 2006; Mortimer and Scott 2003). Meaning is made by gaining an understanding of the substantial knowledge in a conceptual framing mediated throughout language and other artefacts. Understanding dialogues and classroom discourse is subsequently of uttermost importance when we want to understand and improve learning in science classrooms.

It is commonly accepted in the science education community that social processes are important for learning (see Carlsen 2007; Leach and Scott 2003; Lemke 2001a; Mortimer and Scott 2003; Wellington and Osborne 2001). The learner meets new ideas and concepts in social situations and these are tested in cooperation with others in a range of different forms of communications like talk, gestures, writing, visual pictures and actions. An important part of the social trial of ideas and concepts involves learners comparing their conceptions, in addition to comparing them with clarified conceptions of science (Scott et al. 2007). The participants reflect and make meaning of what is being communicated in the situation. Mortimer and Scott (2003) describe learning as both individual *meaning making,* where you reconstruct old and new ideas, and dialogical *meaning making*, where ideas are given a language in a social context. Speech and language become essential tools in the process of acquiring knowledge of science in the classroom.

Mortimer and Scott (2003) consider language as a fundamental tool for learning, and they have studied different features of the spoken language in science classrooms. They focus on the distinction between everyday language and scientific language, based on Vygotsky's notions of everyday and scientific concepts

(Vygotsky 1978) and how these sometimes are in conflict. For instance, the concept of *energy* may be understood in different ways in an everyday context and a scientific context. They focus on three central features of scientific language: *description* (providing an account of a system, object or phenomenon); *explanation* (importing a theoretical model to account for a phenomenon) and *generalization* (description or explanation independent of a specific context). They also note if the content refers to *empirical* (observable) or *theoretical* terms. In addition, they find the communicative approach (interactive or non-interactive) in the classroom talk significant.

Explanation in science has been defined over as importing some form of a model or mechanism to account for a specific phenomenon (Mortimer and Scott 2003). Ogborn et al. (1996) point at some of the dilemmas of explanations in science classrooms. They focus on the importance of understanding the entities that models consist of before you come to the actual explanation, and the observation that explanations provided in school science are often answers to questions posed by the teachers or the curriculum and not by the students themselves. This is quite different from the genuine inquiry you find in science. "If in science itself, phenomena can be envisaged as in need of explanation, in teaching science it is almost the other way around. The existence of an answer is the reason for posing the question." (Ogborn et al. 1996, p. 131). This leads to the conclusion that one of the crucial responsibilities of science teachers is to motivate students to 'want what they need'. Subsequently, "... much explanation in science classrooms is not the explanation of phenomena, but is the explanation of resources the student needs in order to explain phenomena. [...] For these reasons, much of the work of explaining in science classrooms looks like describing, labelling or defining. [...] The entities which are to be used in explanations therefore have to be 'talked into existence' for students." (Ogborn et al. 1996). What is the role of explanations versus descriptions in our classrooms? Are the students given opportunities to engage in everyday *and* scientific language practice?

In his book *Talking Science* Jay Lemke (1990) describes *meaning making* as a process where you connect things with context. Actions and incidents become meaningful when they are contextualized. He claims that you learn science by learning to use scientific language; this is essential not only for understanding scientific concepts, but also for grasping the structures and thematic patterns that are disclosed by how science is portrayed. Lemke defines thematic patterns as "shared semantic patterns common to all different ways of saying the same thing" (p. 27); a repeated way of communicating. An example is: "This plant is a monocot because the sprout has one leaf." A thematic pattern here is that, in science, plants are classified and labelled (a monocot plant). Another is that the classification is explained by a characteristic of the plant (the plant germinates with one leaf). The way the teacher communicates thematic patterns through classroom dialogues and monologues, is also a part of learning science. Students have to learn this pattern in order to master talking about science, understanding the nature of science and using this knowledge to solve problems and tasks connected to science. While making meaning of the language of science students use everyday language as support. Lemke (1990) calls this mix of languages *interlanguage*. Olander describes how students use a similar hybrid language, when they try to understand evolution (Olander 2010). Teachers who are aware of this distinction can assist their students' learning by helping to bridge the students' path to scientific language via hybrid language (Gomez 2007; Lemke 1990).

In our video analyses of discourse and language features we mainly draw on the works of Mortimer and Scott (2003) and Lemke (1990). Together, Mortimer, Scott and Lemke shed light on how conceptual language, coding categories and timescales are significant in analyzing meaning making in science classrooms. However, further analyses on even smaller timescales may enrich the data concerning the influence of student initiatives (Barnes et al. 1969) and the significance of explanations and teacher questioning (Ogborn et al. 1996; Wellington and Osborne 2001).

7.3 Design and Data Sources

In this video study six Grade ninth classes (students aged 14–15 years) at six different schools were followed for 2–3 weeks in science. In total we videotaped 45 science lessons. The lessons were filmed using three surveillance cameras: one remotely controlled following the teacher, one capturing the whole class and one focusing on a small group of students, usually two. The small student groups were interviewed immediately after the lesson. We also conducted video-stimulated interviews with teachers. For more details about the methodological design and set up for the whole study, see the Introduction to this book, or Ødegaard and Arnesen (2010).

7.4 Analysis

To make profiles of classroom talk and language use across classrooms, each lesson has been coded on different levels and with different conceptual scales using the software programme Videograph®[1] (Rimmele 2002). The software gives us an overview of the occurrence and time use of the different codes. The lessons in all subjects were coded regarding instruction format in order to characterize typical lessons in mathematics, science and reading, and to expose similarities and differences between subjects and schools (see Introduction). A second level of coding was performed on the science lessons to characterize them more exactly (Ødegaard and Arnesen 2010).

[1] Videograph ® is a computer software programme developed at IPN, Kiel, http://www.ipn.uni-kiel.de/aktuell/videograph/htmStart.htm (*Last visited 31.07.06*)

7.4.1 Coding of Science Lessons

Findings from the comparative analyses of the science, mathematics and language art lessons in this study show that classroom dialogue is the single most used tool in teaching science (see Chap. 2 and Ødegaard and Arnesen 2010). Therefore, as an analytical approach for exploring the complexity of science classroom talk, we have examined features of language, content and dialogue. One of the categories we used for analysis is *social language*, which was designed to capture whether the social language used in the classroom discourse is everyday or scientific in nature. Scientific language is defined as the use of scientific concepts (Mortimer and Scott 2003), and is coded by following the teachers' conversation with the students. It includes both teacher and student talk, in both the whole class setting and when the teacher moves around and has conversations with students, e.g. during practical work and seatwork. (See Table 7.1.)

Another way of interpreting how much the students are exposed to science talk, is to code the content of classroom talk according to *scientific features* brought up in the discourse. Like Mortimer and Scott (2003), we observed that different features of scientific knowledge can be identified in the classroom dialogue between teacher and student. In a science lesson the teacher may emphasize *describing* systems or

Table 7.1 Coding scheme for science (Arnesen and Ødegaard 2006)

Social language	
Everyday	*Teacher and students use everyday concepts and language*
Scientific	*Teacher and students use scientific concepts and language*
Scientific features	
Description	*A scientific phenomenon, concept or event is described*
Explanation	*A scientific phenomenon, concept or event is explained by establishing relationships between phenomenon and concept by using some form of model or mechanism*
Generalization	*Making a description or explanation that is independent of any specific context*
Reference of content	
Empirical	*The object or phenomenon that is described or explained is present and observable in the classroom*
Theoretical	*The object or phenomenon that is described or explained is* ***not*** *present or observable in the classroom*
Features of dialogue	
Student initiatives	*A student makes a comment or asks a question that brings up a new theme or issue. Also includes the answer or comments from teacher or students*
Teacher lecturing	*Teacher presents or explains something by talking without including students*
Teacher initiatives	*Teacher asks questions in order to use or mobilize students' knowledge and/or bring up a new theme or issue. Also includes the answers or comments from students*

phenomena, he can try to *explain* systems or phenomena by using scientific models or mechanisms, or he may *generalize* by giving a description or an explanation without specific context. (See Table 7.1.)

In parallel with coding for scientific features, we coded whether the content knowledge had empirical or theoretical references. If an object or phenomenon that can be observed in the classroom is described or explained, it is coded *empirical*. If it is non-observable, it is coded *theoretical*. (See Table 7.1.)

Within our coding categories of classroom dialogue we have coded for *teacher* and *student initiative*, which is defined as a sequence of questions, answers or comments that is initiated by either the teacher *or* the student. A third code is labelled *teacher lecturing*, which indicates teacher talk without interruption. Unlike teacher monologue (see Introduction), this does not have to last for three minutes (see Table 7.1).

7.5 Findings

7.5.1 Scientific Features and Use of Language in Classroom Talk

In our material, only a small portion (less than 20 % of coded time) of the dialogues between teacher and student contained science talk that could be coded as description, explanation or generalization (see Fig. 7.1). Descriptions of phenomena or systems were the most frequent. The dialogues included few scientific explanations or generalizations (see Textbox 7.1 for examples).

The data material exposes considerable variation. In one lesson about the human skeleton, over half of the classroom talk had a direct scientific focus. In another

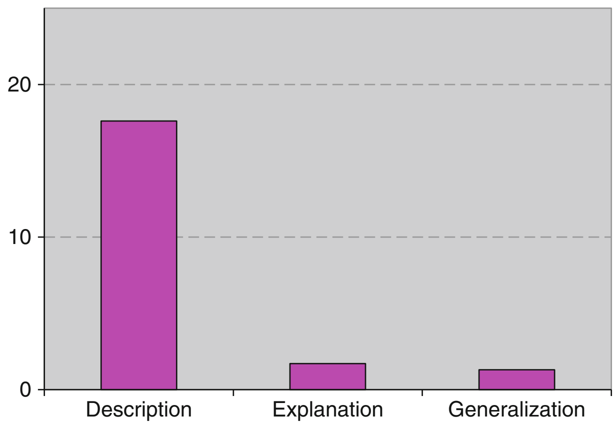

Fig. 7.1 Use of scientific features following the teacher during the whole lesson as a percentage of videotaped science lessons

Textbox 7.1 Excerpt from a science lesson about photosynthesis (S3_080905_0821). Examples of description, explanation and generalization

Description:	T *(drawing on the blackboard)*: It is a seed. I have drawn a seed. Have you seen what comes up from the ground, the first that comes up from the ground? S: One of those little green things. T: Yes. Have you noticed how many leaves there are on it? S: Two T: Yes, good. Excellent.
Generalization:	T: The plant kingdom is divided in two groups. One is monocots, and those are the sprouts that come up from a seed with one leaf. And that is for instance grass [. . .] And then there are dicots.
Description:	They come up with two leaves first. [..like the sunflower..]. *(points to the blackboard)* [. . .]
Explanation:	L: *(shows a sunflower)* What has happened on the way from the tiny little plant to the huge sunflower? How does the plant manage that? E: It produces sugar, and then that is made into a stem like that.

lesson about how to use Classfronter and viten.no (Jorde et al. 2003), which both are web-based learning platforms, the dialogue had minimal scientific focus. However, this does not mean that time was spent mostly on non-scientific talk and activities. Our coding shows us that for approximately 80 % of coded time the work done was relevant to science education. This could be, for example, management of practical work, emotional student support, or talk connected to socio-scientific issues. In the example mentioned above about managing web-based platforms, the whole class dialogue was procedural because the students were supposed to learn about the ICT tools in order to use them later for autonomous work with science content, for instance in viten.no. At this particular school there was a focus on individual students working autonomously using a work plan. Thus, the natural consequence was that the teacher spent time on organizing and preparing the students' work. Likewise, we saw other examples of how teachers used classroom time to prepare students for activities like a farm visit or practical work, where the classroom dialogue was about how the students were supposed to work with the science content later. Even in the skeleton lesson, which had a high level of scientific focus, important parts of the dialogue could not be characterized as description, explanation or generalization. For instance when students philosophized about how the skeleton had evolved, or when the teacher asked a motivational question such as "What holds our body upright?", and gave the students time to reflect upon the question. At other times the teacher drew on cross-curriculum topics, for example asking "what is the word for cancer (kreft) in English?" in a lesson about tobacco and cancer. Later on in the lesson that knowledge was used to explain death statistics from the US, and in that way scientific knowledge about smoking was put in a global societal context. It is important to point out that in the whole class dialogues, led by the teacher, there was a clear focus on science even though, they did not contain a direct description, explanation or generalization.

Table 7.2 Cross table between features of science and classroom talk, as a percentage of total talk time

Class-feature room talk	Science			
	Description	Explanation	Generalization	Other
Student initiative	24 %	4 %	1 %	71 %
Teacher initiative	34 %	4 %	3 %	59 %
Teacher exposition	25 %	2 %	3 %	70 %
Annet	4 %	0 %	0 %	96 %

Earlier we showed that in the interactive part of the teacher–student dialogues, the students influenced the dialogue almost as much as the teacher by initiating comments and questions (see Chap. 2, and Ødegaard and Arnesen 2010). By cross-tabulating the categories for classroom dialogue and scientific features (Table 7.2), we see that one-third of the student initiatives in our study contain a scientific description, explanation or generalization, with emphasis on descriptions. Our data indicate that the student initiatives include almost the same amount of scientific focus as the teacher initiatives.

However, when the students worked in groups (often on practical work), the guiding dialogue between teacher and students had a lower level of scientific focus. In our lessons these dialogues included less than 5 % descriptions, explanation or generalizations. The teachers spent their time on organizing students, activating all learners, getting equipment and answering practical questions. Both teachers and students focused on getting the work done, rather than focusing on what they were supposed to learn from the activity. Thus, these dialogues had strong procedural features.

The impression of that practical work is not used as an opportunity for talking about science was increased when we studied which *references* were used in the teacher–student dialogues. We found twice as many *theoretical* references as *empirical*. Even though this can vary according to the topic taught, it seems that teachers do not emphasize how students' empirical experiences from practical work can be applied when content knowledge is discussed in the whole class setting. Teachers also seldom used artefacts, demonstrations or practical work to illuminate scientific theory. We saw few examples of teachers attempting to create bridges between practical work and theory of content knowledge.

The category we named *social language* was designed to capture whether the language used in classroom talk is everyday or scientific. Our coding showed that there was three times more use of everyday language than scientific language. However, this category was very difficult to code in a satisfactory way. Scientific language is defined as the use of scientific concepts. Nevertheless, this is not a meaningful and accurate definition. By coupling the categories of *social language* and *scientific feature* we found observations of scientific features without the use of scientific concepts; for instance "The little green thing has two leaves when it comes up from the ground" – a description of a dicot sprout. We also found the

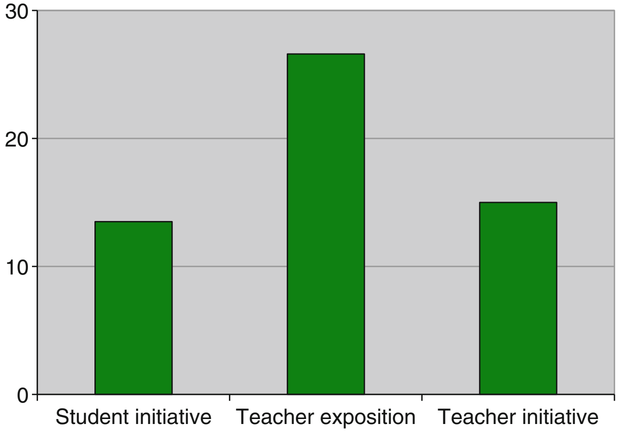

Fig. 7.2 Classroom dialogue during teacher led instruction as a percentage of videotaped science lessons

use of scientific concepts without scientific content, e.g. "Remember to couple with direct current. First you couple in series, then in parallel." Aspects of everyday and scientific language, and possible use of a hybrid language linking the two, require further in-depth analyses of selected dialogues. Even so, the overview analyses presented here show us that generally in science lessons there is little systematic use of scientific language in the form of concepts.

7.6 Discussion

7.6.1 Language and Science

It is claimed that learning science involves being introduced to the language used in scientific society (Mortimer and Scott 2003). At the same time it has been pointed out that academic scientific language is not the same as the language of school science. Lemke (2001b) states that scientific language is not just specialist vocabulary, and that it is possible to discuss a topic very scientifically without heavy use of technical vocabulary. The scientific words in themselves are not as important as their essential and conceptual meanings. Their usefulness comes from their connections to one another (Lemke 1990). Both Brown and Spang (2007) and Olander (2010) found in their studies that students lean on a double or hybrid language when they explore the language of science. They try to explain the scientific terms in their own words, and subsequently develop their own school science language.

Our analyses of the talk in science classrooms demonstrate that it is hard to distinguish between scientific language and everyday language, and we will need to develop an alternative and more detailed analytical approach, in order to learn more about language in science classrooms. Interestingly, Knain (2005) draws attention to the difference between expressive and transactional writing in science. Expressive writing is when the individual writes in order to reflect and understand a scientific phenomenon for her/himself, and thus it consists largely of everyday language. Transactional writing, on the other hand, is aimed at communicating and informing, and is consequently more formal, using scientific language. Hence, the context of the dialogue might influence the use of scientific terms.

Likewise, Yore et al. (2003) indicate that the language scientists use varies with the purpose and setting. When talking with lay people scientists use less scientific expressions and have a more informal style than when they are in an instructional setting with students on a high academic level. However, when teaching a first-year introductory course, scientists approximate the style and terminology for lay audiences. We might be seeing the same pattern for teachers. Their extensive use of everyday language at the expense of scientific language could be an effect to adapt to the individual student's struggle for understanding. An undesirable consequence of the lack of a bridge between everyday and scientific language may be that students will not become acquainted with the use of scientific concepts and scientific language.

7.6.2 Content of Talk

An important part of learning science and understanding the nature of science is the way scientific knowledge and logic is communicated, which is demonstrated through classroom dialogues and monologues led by the teacher (Lemke 1990). When science talk in the classroom mainly emphasizes descriptions, and rarely includes explanations, it may result in a misrepresentation of science as a descriptive subject rather than a means of seeking explanations of natural phenomena. Ogborn, Kress, Martins and McGillicuddy (1996) claim that there are good reasons for a dominance of descriptions in science education, and they point to some dilemmas connected to explanations. Predominately, explanations are answers to questions from teachers or school books, and not from students themselves. This is very different from authentic science, where scientists pose questions in order to seek new explanations to scientific phenomenon (Ogborn, et al. 1996, p. 131). Further, they point to the fact that much of the work of explaining in science classrooms looks like describing, because it has first to provide the material for explanations. We see examples of this in our material. In Textbox 7.2 we see that the teacher first has the student describe a sprout, before she uses the description to explain the division of the plant kingdom. However, the most prominent feature of classroom science talk is description without any additional explanation or generalization. Hence, a consequence is that students might not see the real purpose of science as a producer of knowledge explaining natural phenomenon.

7.7 Final Comment

The science classroom dialogues in our study are characterized by predominant use of everyday language. The teachers seem to make an effort to reach out to the students by both adjusting to their language and including them extensively in the classroom discourse. Even though the teachers use class dialogue as their main mode of teaching, and show that they understand the significance of language when learning science, they do not focus explicitly on science terms and concepts or arrange for the students to practice talking science in a systematic manner. Neither do we see evidence that teachers facilitate the transition from everyday to scientific language, which would enable the students to appropriate and understand science concepts to a greater extent. This is thought-provoking because we see language as an essential tool for learning science.

In the dialogues characterized by scientific language and features of science, we mostly recorded descriptions of natural phenomenon. Explanations and generalizations rarely occurred. However, our investigations do not reveal whether this has significance for students' learning. Classroom talk is often framed by theoretical references that make it harder for the students to understand the content and link it to their own empirical experiences. According to Scott and colleagues (2011), this might create a deficiency in students' meaning making processes. The lack of a bridge between theory and practice is especially noticeable in teacher–student talk when doing practical work. Instead of using the dialogue to link students' understanding of scientific phenomenon to the present practical situation, the talk is mainly procedural. Possibly it is here at the intersection of theory and practice that science teaching has its greatest challenge and potential to increase students' meaning making and understanding in science.

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Chapter 8
How Students Make Meaning from a Teaching Sequence on a Socio-scientific Issue

A Case Study of Meaning Making in Science

Nina E. Arnesen

8.1 Background and Aims

During the last few decades it has become usual, and crucial, to learn science not only as the traditionally taught products of the science communities, but also as a way of thinking and as a tool for citizenship in today's society. One way of learning science is through socio-scientific issues which often are societal questions related to health or environment, where decision making is informed by scientific knowledge as well as knowledge from other areas. In Norwegian science teaching it has become quite usual to do this by, for example, arranging debates in class focusing on a controversy. The past decade has also seen a change towards more student-centred active teaching methods such as use of self-instructing computer programs and debates, as mentioned. This change in ways of working in science lessons creates new possibilities for applying science knowledge, but at the same time it brings new challenges for the learners. It appears that students focus on aspects of activities other than science, and the meaning making of science content sometimes seems to be forgotten.

This chapter presents a case study of a sequence of lessons where students (aged 14–15 years) carry out a debate on genetically modified food. Two students are interviewed after the sequence and also followed during their preparations for the debate, the debate and the summing up afterwards, in order to describe and examine how they make meaning through the sequence. The preparations for the debate are

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done by working through a carefully constructed computer program on genetically modified food. The main questions to be answered in the analysis presented here are:

– Is there evidence for meaning making during the instruction sequence?
– How is meaning making framed and scaffolded during the instruction sequence?

8.2 Theoretical Framework

The view of learning presented here is based on a Vygotskian perspective which states that all learning originates in social situations, and is a process of internalization; a passage from social contexts to individual understanding. In this process, language is of crucial importance (Vygotsky 1978, 2001). Learning science should, according to this view, include meeting new scientific ideas, internalizing them and learning to apply them (Ogborn et al. 1996; Mortimer and Scott 2003). In addition, situations should be created, where the students are allowed to make use of the new knowledge. During this process it can be beneficial to the learning process if the students are made aware of their own existing notions of the concept in question, and whether their notions agree with the scientific explanations of the concept. This can be a useful point of departure when developing a convincing scientific story for the students to grasp (Mortimer and Scott 2003).

Teaching science has traditionally been done by presenting the facts of science – the products of hundreds of years of research. However, during the last couple of decades there has been a growing demand that the nature of science should be included in science teaching, with socio-scientific issues (SSIs) being used as a means of teaching the nature of science. In addition, working on SSIs offers the students possibilities of applying their scientific knowledge in broader settings (e.g. Sadler 2011; Hodson 2003). Researchers state that argumentation is of special importance in science education because the credibility of scientific knowledge relies heavily on the soundness of the evidence and arguments supporting it. Therefore science education should, in addition to introducing the students to the scientific story and concepts, promote the understanding of constructing and using arguments to support a claim or point of view (Driver et al. 1996; Jimenez-Aleixandre et al. 2000; Duschl and Osborne 2002). Millar and Osborne (1998) claim that there is a growing body of evidence that when students engage in argumentation this generates a kind of knowledge and understanding essential for scientific literacy. They may, however, discover that there are differences in how arguments are constructed in a scientific debate compared to how they are constructed and used in socio-scientific debates. Scientific arguments contain claims that are explanatory conclusions or descriptive frameworks. This is not always the case in socio-scientific debates (Sampson and Clark 2006). During recent decades several studies on student argumentation and the use of socio-scientific debates in science instruction have been published. Various analytical methods have been used to assess the arguments students use. Most of these analytical frameworks have been influenced by Toulmin (2003). These studies have yielded valuable information on the structure of students' arguments. They say little, however, about the quality of the content of the arguments or to what extent students understand how evidence is used to construct a scientific argument (Sampson and Clark 2006). Some recent studies have taken the content into account in various ways (e.g. Mork 2005; Zohar and Nemet 2002). Other researchers have developed frameworks that take into account the epistemic and/or conceptual qualities of arguments (e.g. Kelly and Takao 2002; Sandoval and Millwood 2005). Several studies show, however, that students tend to rely on short arguments consisting of a few or only a single claim when convincing other students of their ideas, and they tend to rely on a single piece of data to support their claim (Kelly et al. 1998; Sandoval and Millwood 2005).

It is believed that students can hold more than one single notion of a concept; that a conceptual understanding actually consists of different or slightly different meanings. These different meanings form a conceptual profile, following Mortimer & Scott (Mortimer and Scott 2003; Mortimer 1995). This profile can contain different, but accepted meanings of the concept, or it could involve alternative conceptions rooted in, for example, everyday use of a concept (Mortimer 1995). When students are exposed to a scientific idea, they can probe their understanding of this idea, and sometimes they reject their former understanding, and sometimes they stick to it. Sometimes, perhaps most of the time, their former understanding will continue to exist alongside the newly introduced concept. It has been shown that students may switch between different explanations of a concept according to the situation. They use 'science language' in the science classroom, but not anywhere else (Aikenhead 1996; Costa 1995). Which explanation they use is dependent on how the scientific story is told, and how deep their former conviction is (Cobern 2000).

Mortimer and Scott (2003) introduce a framework for analysing and characterizing the patterns of the teacher's classroom talk. The framework takes into account the focus, approach and actions of the teaching, and makes a useful tool for analysing teaching sequences. It identifies six different *purposes of a teaching* action: (1) opening up a problem, (2) exploring students' views, (3) introducing and working on students' views, (4) guiding students to work with scientific ideas and supporting internalization, (5) guiding students to apply the scientific view, and (6) maintaining the development of the scientific story (see Fig. 8.1 below). The communicative approach is also seen as an important feature of classroom talk. It is central to Mortimer and Scott's framework because it provides a perspective on how ideas are developed in the classroom. Is it solely a scientific way of thinking that is presented, or are other ideas taken into account as well? Also, are the ideas weighted differently or are all ideas equally important in explaining a scientific phenomenon? In addition to these factors, the framework takes into account the *teacher's interventions*. Six different aspects are identified: shaping ideas, selecting ideas, marking key ideas, sharing ideas, checking students' understanding, and reviewing the issue in question (see Fig. 8.1 below). Together these different categories make a framework suitable for analysing lessons or sequences of lessons in order to

Teaching purposes	Teacher interventions
- Opening up the problem - Exploring and working on students' views - Introducing and developing the scientific story - Guiding student to work with scientific ideas and supporting internalization - Guiding students to apply, and expand on the use of, the scientific view; handing over responsibility for its use - Maintaining the development of the scientific story	- Shaping ideas - Selecting ideas - Marking key ideas - Sharing ideas - Checking students' understanding - Reviewing

Communicative approach; whose voices can be heard?

	INTERACTIVE	NON-INTERACTIVE
DIALOGIC	Interactive dialogic	Non-interactive dialogic
AUTHORITATIVE	Interactive authoritative	Non-interactive authoritative

Fig. 8.1 Mortimer & Scott's analytical framework revised for the analyses done in this chapter (Mortimer and Scott 2003)

study how the teacher's talk is orchestrated so that the students can make meaning of the content. In addition to the above-mentioned factors, Mortimer and Scott's original framework (2003) takes into account the pattern of discourse and also the science content in question. For the patterns of discourse Mortimer and Scott make a distinction between dialogic and authoritative approaches. In a dialogic approach both students' views and the scientific view of a phenomenon are presented. The students can thus be made aware of any discrepancies between their view and the scientific view. An authoritative approach makes room only for the scientific view. A key point in Mortimer and Scott's framework is, however, that effective teaching lessons should include both dialogic and authoritative discourse, achieved in both interactive and non-interactive ways. In this chapter, the three categories described in Fig. 8.1, teaching purpose, teacher interventions and communicative approach, are used in order to study in more detail the opportunities for the students to make meaning through the teaching sequence. The pattern of discourse and the content of the lesson are not analyzed.

8.3 Methods and Samples

This chapter reports on an in-depth study of one sequence from the science lessons ($n = 15$) in the collected data material in which gene technology was taught to a group of 18 students aged 14–15 years, and which ended with a socio-scientific debate on genetically modified food. The students in this particular group were taught together for 1 day (5 h) a week for 5 weeks on gene technology. The research team was present on three of these 5 days (covering 15 lessons). The students prepared for the debate by going through a computer-based teaching unit on gene technology. In addition the teacher taught central topics, for example, the composition of the cell. The debate was conducted using two students as moderators and four students as a panel; two were supposed to have a positive attitude towards genetically modified food, and two students acted as sceptics. The rest of the students formed the audience and were supposed to ask questions and comment upon what the participants in the panel said. The teacher did not take part in the debate at all nor act as moderator. She was, however, present, taking notes and preparing for the summing up after the debate.

The material used in the analysis consists of video data from whole class lectures ($n = 6$), the group work at the computers ($n = 5$), the debate and the summing up of the debate. In addition important information and the point of departure for the analysis are drawn from the video-based student interview after the debate. The transcriptions are taken from the videos, and for the interview transcriptions are also taken from recordings made with an audio recorder. The transcriptions are done in Norwegian by the researcher and later translated into English. They include everything that is said, as far as possible. For an overview of data collected, see Fig. 8.2.

To study how meaning is made by the students during the teaching sequence, a student interview after the debate was taken as point of departure for the analysis of the sequence of lessons. Two students were interviewed, a boy, Edward, and a girl, Rowena. They were 14 years old and were in Grade 9. During the debate they acted as a part of the audience. During the preparations they worked in different groups in week three. They worked together and were filmed on the day of the debate and hence they were interviewed together. The small group filmed consisted of one more student, a boy, Henry, in addition to the two interviewed. During the interview the students were allowed to see the video from the lessons the same day in order to comment upon selected scenes.

Three answers given during the interview are used to look more closely at how the students' notions of genetic modification develop. The answers concern more

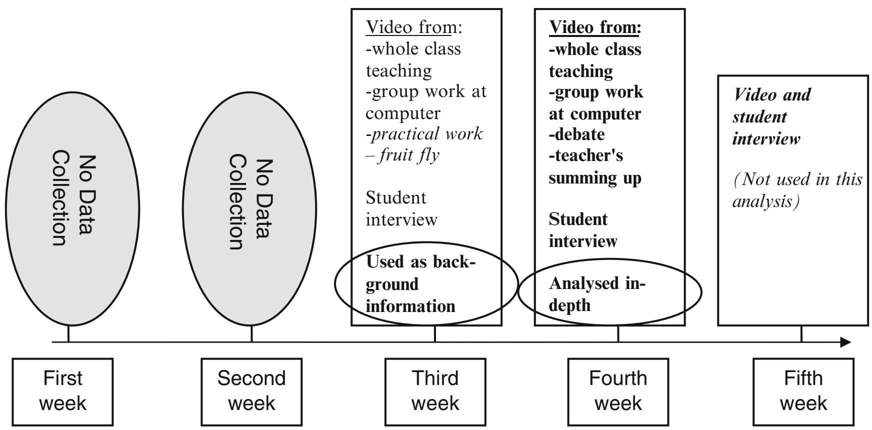

Fig. 8.2 Collected data material from the 5-week gene technology course. Data used in the analysis of students meaning making during a socio-scientific debate is collected from week 3 and 4

or less the same phenomenon: how to genetically modify an organism. The three questions from the interview are the following:

1. "*What did you learn during today's lessons?*"
2. "*What do you do to genetically modify for instance tomatoes or other organisms?*"
3. "*How do you make tomatoes that are resistant to freezing?*"

To describe and possibly explain these differences and in order to see how meaning develops, the students are followed through the preparations prior to the debate; the debate and the teacher's summing up. Four different situations are taken into account in the analysis, in addition to the interview;

– A sequence from the group work in front of the computer. The teacher is present and supervises the group when discussing how genes are modified.
– Three statements during the debate.
– A sequence from the summing up after the debate where the teacher explains how genes are modified.
– A text about Roundup from the Viten-programme.

8.4 Findings: The Students' Answers to the Three Questions

In this section the content of the three students' answers is discussed and traced back through different parts of the preceding lessons. The students' answers to the three questions are presented in Table 8.1.

These three extracts from the interview show that the two students (Rowena and Edward) have some scientifically correct conceptual understanding of what gene modification is, some of their thoughts seem a bit unclear and fragmented, and some of their answers represent some kind of alternative conception of phenomena connected to genetically modified food.

In Extract 1 Rowena rather hesitantly and disjointedly gives an explanation of how gene modification is done. It is, however, never made explicit that this is in fact what she explains. She and Edward use concepts like "DNA" and "enzyme" and seem to have a fairly good understanding of how the DNA is manipulated.

In Extract 2, however, where they are asked explicitly how an organism can be genetically modified, their explanation differs significantly from their first answers. They do not mention DNA, and they seem to have the notion that the gene modification is done in the field by spraying something (Roundup) onto or into the fully grown organisms, "*I020 E: They lie on the fields, then, and you sort of you spray them . . .*"

In Extract 3, the question concerns genetically modified tomatoes, and this time the students' explanation seems to combine the explanations from Extracts 1 and 2. They seem to have a more or less correct notion of how and why gene modification is done, and, in addition, at least one alternative conception of it. These concepts

Table 8.1 Three answers from the interviews used as the point of departure for the analysis of meaning making by two students during a teaching sequence on a socio-scientific issue

Extract 1. "*What did you learn during today's lessons in science?*"	**Extract 2**. "*What do you do to genetically modify for instance tomatoes or other organisms?*"	**Extract 3**. "*How do you make tomatoes that are resistant to freezing?*"
I001 R: Then I learnt how it got.. how one got a new . . . which was on the blackboard earlier . . . (*shows with her hands in front of her on the desk*)	I020 E: They lie on the fields, then, and you sort of you spray them . . . or	I032 I: What was the answer to that question? How do you make tomatoes resistant to freezing?
I002 E: DNA-molecule	I021 R: Like you take . . .	I033 R: You spray on that stuff Roundup
I003, I004 R, E: Yes	I022 E: Yes	I034 [. . .] R: That was when you used Roundup!
I005 R: The DNA-molecules. How one got in a new . . .	I023 R: You take, er, stuff (to E) What was it called, that stuff? Roundup! And then get it into the tomato and then it spread . . . sooo . . .	I035 I: Yes?
I006 E: DNA or molecule	I024 E: Becomes.. like, they grow much faster and propagate	I036 R: And then inject it because then it happens like we explained it earlier, that . . . You divide a DNA
I007 R: (*Looks at E.*) What did she call it?	I025 R: Mm	I037 I: Mm
I008 E: Enzyme or something divided it and then . . .	I026 I: Mm	I038 R: and then you put in DNA from a fish or something . . .
I009 R: Yes, how we got, er, a new DNA, like, into that DNA. Without eh, yes	I027 E: They grow much faster and get more. So you get a larger crop	I039 R: which lives in cold water
I010 I: Yes. Can you, do you want to tell me how it was done?	I028 I: Why do you do this, then?	I040 I: Okay?
I011 R: Um. We had a DNA-line. (*Shows it with her fingers on the desk in front of her.*) Then . . . they cut it in two pieces	I029 R: To make the food keep longer and maybe become a bit larger and stuff like that	I041 R: And if we take it into . . . the DNA of the tomato, [. . .]
I012 I: Mm	I030 E: To get . . . And to get more	I042 R: then it kind of learns to keep . . . learns to stand cold
I013 R: Then they took it in and then they pasted the upper part on that one and then the lower part on the other one	I031 R: Because if you don't do that, then a lot will become rotten very fast. In the field and stuff	
I014 I: Yes. Okay. Er . . . When you say that one cuts and pastes. How is this actually done?		

(continued)

Table 8.1 (continued)

Extract 1. "*What did you learn during today's lessons in science?*"	**Extract 2**. "*What do you do to genetically modify for instance tomatoes or other organisms?*"	**Extract 3**. "*How do you make tomatoes that are resistant to freezing?*"
I015 E: One . . . one takes it is called enzyme which one takes and then divides it in the middle and then . . . yes, and then one opens and puts a bit . . .		
I016 I: Mm		
I017 E: Yes. A new molecule		
I018 R: I don't know exactly how . . .		
I019 R: you get to paste it back on		

R Rowena, *E* Edward, *I* Interviewer

can be seen as two different parts of a concept profile and the extract shows use of the different parts according to the situation (Mortimer 1995; Mortimer and Scott 2003). However, the students do not appear to be aware of the fact that they use different explanations for the same phenomenon in different situations. In addition, the two students' concept profiles of the concept in question most likely differ, but their explanations do not differ significantly during the interview and they do not argue against each other. Therefore they are treated as one concept profile.

8.5 How Meaning Is Made and Apparently Changes During the Teaching Sequence

The students' concept profile can possibly be partly explained by tracing the development of the concepts through different parts of the teaching sequence. In the following section, three episodes of importance for the meaning making process are analyzed: the work in front of the computer, the debate and the summing up towards the end of the day.

8.5.1 In Front of the Computer

One sequence of possible importance for the development of the students' conceptual profile took place in front of the computer. Here at least two different notions of the concept of genetically modified organisms can be recognized. The idea that genetic modification of an organism is connected to spraying might come from a page in the computer programme which shows soya beans resistant to Roundup, an herbicide, through gene modification. It seems that Rowena, at least, holds this view during the work on the computer programme on genetically modified food. The following episode takes place with the teacher present with the three students at the computer:

(The students are preparing questions for the panel later on. Edward suggests that they could ask a question on how tomatoes resistant to freezing are made.)
E: We could. How do you make frost resistant tomatoes?
R: You just spray on that stuff.
E: Pardon? (Turns to look at her.)
R: Isn't it just to spray on that stuff? [. . .]

It appears that Edward doesn't agree with Rowena about the spraying explanation at first; at least, he turns to her and looks as though he does not believe what he has heard. He adopts the idea quite easily, though, but there might be a slight difference between their concepts. While Rowena starts out by saying that something is sprayed *on* the tomatoes, Edward talks about something sprayed *into* them:

E: We could write What kind of stuff is it that y.. they spray into it!
Teacher: They have to go inside and change the genes.

While the two students discuss how to formulate their question, the teacher tries to give them an alternative idea of how genes are modified, but they seem quite preoccupied with their own conception of it. They keep reformulating their question on what is sprayed into the tomatoes, but the teacher does not give in:

[. . .]
R: What kind of stuff is it they spray into the tomatoes to make them frost resistant?
Teacher: Yes . . . but.. I think they have been in there to cut and paste already at the first cell stage after the fertilization. Like, when the tomato plant, it grows, true?

Now it seems she gets attention, at least from Rowena, who starts answering affirmatively after each statement from the teacher.

Suddenly the third student, Henry, makes an important comment which shows that he has got the whole thing right. However, the others do not seem to notice what he says. The teacher gives a little confirmation, but the other two students do not seem to react or hear what is said at all:

Henry: It is not the spraying that made them frost resistant.
Teacher: So you have to go in and change the genes. That's what genetically modified means.
Henry: They changed the genes so that they **became** resistant to the spraying.
Teacher: Mm.
R: Yeah, but . . .
Henry: It was not the spraying that . . .

After some more explanation from the teacher, it still seems that Rowena has stuck to the notion that something is squirted into the tomato. Edward, on the other hand, has become quite impatient, and might not be listening anymore:

R: Do they do it on every tomato in the whole world?
Teacher: No, but if they do it on one, then the children will have the same properties.
R: Oh, yes. Yes! If they do it on one, they do it on all!
Teacher: Yeeah.. They do it on some.
R: So, like, they go and give a squirt, like, there you are, one for you?
Teacher: Hehehe.
[...]
Teacher: They do not spray it in!
E: We could go further down (Referring to something on the screen)
Teacher: They do something in the lab first. To the genes. Get it?
[...]
Teacher: But the DNA molecule is two threads. And then, if you want to put in another gene, you can cut it, and then you can put in an extra gene, for instance.
R: Yes, and then you get one that...
Teacher: This is done by using certain enzymes.
R: one that...
Teacher: In the lab. And then you put it back into the egg cell.
E: (Yawns) Yes. Okay. We know what it is. We know what it is. It is just you (Referring to R) that don't know what it is. [...]

In this sequence, it seems that Rowena is a bit confused at first, and thinks that you make the plants resistant to frost by spraying something on them or into them, but after a while she accepts the idea that you have to go into the cells and do something to the DNA to genetically modify an organism. This is also the explanation she presents during the summing up in class towards the end of the day, and also when answering the question: "*What did you learn today?*". The last part of the dialogue in front of the computer could, however, indicate that she still sees it as something that is injected or sprayed, although now it is into, not onto, the tomatoes.

8.5.2 The Debate

This notion, that gene modification can be done by spraying something onto or into the organisms, might be strengthened during the debate. Here at least one of the students in the panel, Claire, and one of the moderators, Keira, seem to confuse genetic modification and spraying of food, especially connected to Roundup:

D028 Claire (In the panel): But, anyway, it is much easier for the farmer to... to grow it because of when you go over. You don't

	need to spray using poisonous herbicides and then it is better to use genetically modified. Yes, then it becomes easier to... then it becomes less work because, erm, the weed, it dies if you do it in this way. [...]
D040 Claire:	Yes, it does if you use... if you use this... if you genetically modify them, then... you spray them. I don't know exactly what you spray myself, but anyway they spray. I suppose they use... yes! now I know what they spray.
D045 Claire:	Roundup.
D052 Keira (moderator):	Have those who sell.. or buy your crop become more or less positive after you started to spray it. Your crop?

This dialogue shows that other students also confuse spraying and gene modification. This may be explained by the fact that one of the pages in the computer program which the students use in their preparations for the debate contains information on the herbicide Roundup, and the students seem to have difficulties understanding the difference between the herbicide and the gene manipulation done to organisms in order to survive the herbicide.

8.5.3 The Summing Up Towards the End of the Day

In Rowena's answer to the question "*What did you learn during today's lessons?*" she actually refers to the teacher's explanation of gene modification in the summing up by saying "*...which was on the blackboard earlier...*" In the sequence she refers to, the teacher explains and illustrates how DNA is modified:

S383 Teacher:	Okay. If we imagine having the DNA thread of... the plant. We are going to improve that plant by add a gene we are really interested in. For instance this gene that stands cold, the tomatoes were going to stand freezing. To do this, you take a gene from a fish that lives in cold water and puts it into the DNA molecule. How can one do that?
S384 R:	Cut off half of it and paste on.
S385 Teacher:	Yes. You can cut off in the middle here (Points to the drawing on the blackboard.) Like this. Then you have two pieces. Divided.
S386 R:	And then paste on.
S387 Teacher:	And then you can take them apart and put in another gene. Then you put in the gene you are interested in. Let's see... Like this! (Draws a line across the DNA threads on the blackboard.)

Here Rowena takes part in the summing up and shows that she already has an idea of some sort of cutting and pasting when genes are modified, and she shares this idea with the class and the teacher, but in spite of already having the notion as a part of her concept profile of the concept "gene modification" in this situation, she refers explicitly to the summing up when she is asked later what she has learnt during the day. This might be due to the fact that the teacher explains the concept thoroughly, and when she senses that many students do not get it, she explains once more while she tries to scaffold the students' understanding by using three pens to illustrate the three parts of the DNA:

412 N: Do you get it? If you take like . . . (Takes two pens from the desk and uses them to illustrate the two parts by putting them together.) Here we have the DNA, like this. Then we want to put another gene into it. Then you cut like this. (She takes the pens apart.) Then we have two pieces like this. And then we put the other gene in between. (Uses a third pen between the two first to illustrate.) Like this. And then we paste them together. Now we have a new gene into it.

R: Cool!

8.6 Discussion and Implications

In this sequence of lessons on gene technology and genetically modified food most of the six teaching purposes listed in the framework by Mortimer and Scott (2003) are present. Before the students start working on the computer program, the teacher reviews important concepts and facts connected to gene technology. This can be seen as a way of opening up the problem to the students (Mortimer and Scott 2003; Fig. 8.1). During this first review, key ideas are shaped and marked (ibid.). The computer program provides possibilities for the students to work on and explore their own ideas, as well as being introduced to the scientific story (see Fig. 8.1; upper, left square). The fact that they meet both their own ideas and the scientific story during their work is, however, not expressed explicitly.

The preparations for the debate can be said to be a situation where the students apply and expand the use of their new knowledge (see Fig. 8.1; upper left square). The preparation for the debate in front of the computer shows, however, that they are more focused on producing difficult questions for the panel to answer than understanding and using their new knowledge. They base their question ("how are tomatoes made resistant to freezing?") on single details from the scientific story told by the computer program. This is in accordance with Kelly et al. (1998) and Sandoval and Millwood (2005), who point to the fact that students who take part in argumentation tend to use single arguments based on one claim and few pieces of information.

The debate is also a situation where the students have the opportunity to apply and expand the use of the scientific view, and, in addition to this, have responsibility for its use (Mortimer and Scott 2003; Fig. 8.1, upper left square). In the debate analyzed here, two students act as moderators. This gives the students the extra responsibility of checking the understanding of the concepts in question (Mortimer and Scott 2003). When students are moderators, the teacher has less scope to intervene and help with selection and review of ideas and understanding (see Fig. 8.1; upper right square). In this particular case, the teacher makes thorough notes during the debate, and by doing this she is checking the students' understanding of important concepts. She uses the last part of the day to review some of the scientific ideas that are brought up during the debate. They are shared and reviewed, and again the teacher checks the students' understanding by asking questions (ibid.). The fact that this summing up is done a while after the debate might lead to a lack of bridging between the debate and the summing up and hence make it harder for the students to check out their understanding and make meaning of new knowledge.

Features of the communicative approach may also be of importance when it comes to meaning making for the students. The dialogue is characterized by a high degree of interactivity, and perhaps sometimes a lack of an authoritative voice representing the scientific view. An example from the group work is when the teacher says: "They have done something to the genes, *I think. I don't think* it is just to spray on like . . . ". It sounds as if the teacher is not quite sure what is right, and this might make the students think that they can actually argue the statement. The extract from the group work in front of the computer also shows that the authority of a statement might be dependent of who put it forward. Although the student Henry explains the connection between Roundup and gene modification accurately, nobody seems to pay attention to what he says. Once again this points to the critical role of the teacher in making key ideas and key concepts explicit through their deliberate use of authoritative voices, either their own or those of competent students. The analysis shows that the students have made meaning of new information that came up during the sequence of lessons and activities. In the present case study, the students interviewed know towards the end of the day that to genetically modify an organism, you have to go into the cell and manipulate the DNA molecule. This notion exists, however, parallel to and at the same time as an alternative conception of genetic modification as something "you spray on . . . ". It also seems that there is no conscious connection between the two conceptions, and the students do not appear to reflect automatically upon the fact that they use different explanations for the same concept in different situations. The students also seem to be uncertain of how to use their knowledge, for example, in scientific arguments, during a debate.

When student-centred and student active methods are used in the classrooms, new challenges in the process of meaning making and scaffolding this process will be raised. Knain et al. (2011) point to the importance of framing the process by changing between open phases and phases that are more strictly and explicitly related to the scientific story. Mortimer and Scott's framework reflects these shifts and, as shown, most of their teaching purposes can be identified in the present case study.

Wallace (2004) states that being able to use both scientific and everyday language in different ways and settings is central to the process of meaning making.

The situations where students negotiate meaning without necessarily knowing the scientific answer are also important. In the sequence of lessons analyzed here, the students meet the scientific story, they negotiate meaning and they use both scientific and everyday language, but they are not necessarily aware of the process and why they do this. To make the purpose of the learning process clearer and hopefully help bridge the gap between the scientific story and the students' own conceptions, one could use meta-learning. This could, for instance, be done by videotaping the lesson (debate) in question, and then commenting upon situations where alternative conceptions are brought up or where knowledge is used in ways that can serve as models. The bridging between the scientific idea and the debate, and the comparison between the different notions expressed by the students could also be more explicitly handled by the teacher, for example, by playing the role of moderator during the debate (Mork 2005).

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Chapter 9
Conversations as Learning Tools in Mathematics: What Do Pupils Actually Learn?

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9.1 Introduction

The theme of this chapter is to discuss challenges associated with the use of classroom conversations as learning tools in mathematics in lower secondary school. Conversations as learning tools – be it whole class discussions or conversations in pairs and groups – have received a lot of positive attention within mathematics education over recent decades. Researchers around the world have argued that students generally should be given more opportunities to actively participate in academically related mathematical conversations and discussions (Cobb et al. 1997; Cobb et al. 2000; Sfard 2000, 2001; Sfard and Kieran 2001; Van Oers 2001; Jaworski 2005; Kazemi & Franke, 2004; Lampert and Graziani 2009).

To change the way mathematics classrooms function to discursive communities of teachers and students is, however, challenging (Walshaw and Anthony 2008). Such changes require more than new descriptions of teaching and learning in academic programs or in curricula. They presuppose basic transformations of interaction patterns between teachers and students and, more importantly, a broader and distinct repertoire of communicative skills; the ability to talk *in* and *about* mathematics. Such skills must be developed by both teachers and students. In this chapter, we will argue that teachers need to have instructional and communicative competence in leading and managing classroom conversations if these are to function as 'discursive learning communities of teachers and students'. Such expertise is essential for teachers to succeed in supporting students' verbal reasoning

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in a way that promotes mathematical understanding (Boaler 2005). We argue that ‘mathematical discourses’ as learning tools in mathematics currently appear to be weakly developed, and if such conversations are going to enhance learning, they need to be backed by specific procedures, guidelines and tools to ensure high quality mathematical reasoning.

The analyses presented in this chapter are based on classroom observations and video analyses of two consecutive math lessons in one particular classroom participating in the PISA+ Study. In these lessons, actual newspapers and quotations from newspapers were used as devices and starting points for discussions of mathematical representations (graphs, pie charts, percentages etc.). The two session sequences consisted of one lesson of pair work, in which the students were given the opportunity to interpret, discuss and analyze the relevant material, and one lesson of teacher-led whole class discussion. In this last session, the teacher asked all the student groups to actively contribute with their various solutions to the common problems they had been working on, and she encouraged everybody to take part in the subsequent discussion.

The structure of this newspaper session illustrates some key challenges connected to the teaching of mathematics in general and the role of mathematical conversations in this particular lesson. First, the teacher’s plan is to make a clear link between the students’ mathematical reasoning and real world issues taken from actual newspapers. This is done to ensure that the students see mathematics as relevant for their own lives, an issue often discussed within mathematics education (Ernest 1991; Gravemeijer 1994). Second, the teacher uses mathematical discussions in pairs (pair work) and by the whole class as a learning tool to develop students’ mathematical understanding. This has been another pressing and much-debated issue within mathematics education. The teaching of mathematics has repeatedly been found to be dominated by teacher instruction and individual seatwork, and many researchers have emphasized the importance of a more varied repertoire of learning activities, with a particular focus on increased student participation (Kilpatrick et al. 2001; Lampert 2001; Boaler 2002; Ball 2003). Based on the analysis of the two lessons described above, the following research issues will be addressed:

– What kind of mathematical reasoning takes place when students are engaged through pair work in mathematical conversations relating to issues from everyday life?
– How do students negotiate and allocate responsibility and apply relevant mathematical competencies during the pair work sequences?
– Do the students succeed in interpreting the tasks and relating them to relevant mathematical issues?

All these issues will be discussed in relation to the actual dialogues that were observed during the two-lesson sequence, and in light of relevant theory within mathematics education.

9.2 Theoretical Perspectives

In order to succeed in making mathematics more relevant for students in their daily lives and increasing student involvement in mathematics lessons, it has been argued that school mathematics should include greater use of oral activities (Lampert 1990; Cobb et al. 1997; Boaler 2005). As previously mentioned, mathematical competence has, over the last 10 years, been defined in terms of being able to participate in mathematical discourses and express ones ideas through the use of mathematical symbols and representations (Yackel 1995; Lerman 1996; Cobb et al. 1997; Gravemeijer et al. 2000; Sfard 2000; Steinbring 2005; Cobb 2007). The mathematics philosopher Paul Ernest (1991), for instance, claims that mathematics is characterized by its dialogical character. He argues that we can reach a common mathematical understanding by the use of conversations, and that this quest requires that we provide spaces where different voices can be heard "*based on the logic of question and answer, and on uncertainty*" (p. 3).

Different analytical perspectives used within mathematics education, such as cognitive psychology, social constructivism, distributed cognition, semiotics and socio-cultural theory, all point to the important role of reflective discursive practices in promoting mathematical understanding. Despite various theoretical differences between the above-mentioned approaches, they all emphasize the practice of discursive and communicative skills as essential to the development of mathematical proficiency. How communications or communicative skills are defined within the different analytical perspectives, however, varies. Some scholars underscore that communication as a tool of learning enables knowledge sharing and contributes to public knowledge (O'Connor 1998; Carpenter et al. 1999), others emphasize the possibilities it offers for participation (Lampert 1990; Bauersfeld 1995; Nunes 1999), or see communication as a means to develop mathematical practices through explanations and descriptions (Boaler 2002; Silver and Smith 1996). Some researchers consider conversations as a space where students can share mathematical solutions and ideas (Hiebert et al. 1997), while others stress that mathematical thinking and reasoning is developed through participation in classroom discussions, (Sfard 2001). In addition to their general belief in communication and communicative skills as essential for the learning of mathematics, an important common feature of these views is their close connection to Vygotsky's (1978) central ideas of the zone of proximal development; learning through social interaction with a more competent 'other'.

Recent research, however, has challenged the established 'truth' that participation in mathematical discourses necessarily leads to the development of mathematical proficiency. Cazden (2001), Némirovsky (2005), Sfard and Kieran (2001) and others argue, for example, that teachers must be equipped with adequate instructional tools and have a specific instructional and communicative repertoire of skills in leading mathematical conversations for discourses to function as productive learning situations for students. They argue that more research is needed to expand our knowledge of how participating in mathematical discussions can foster mathematical learning. They also point to the importance of equipping the teachers with appropriate tools for managing the challenging learning situations related to leading mathematical classroom discussions.

Cobb et al. (1997) argue that participation in mathematical reflective conversations, under certain conditions, will stimulate the development of mathematical understanding. The teacher's role in these situations, they argue, is to initiate and control the discussion, and to make interventions that ensure that the conversation always keeps an explicit mathematical focus. It is also the teacher's responsibility to support students in developing their understanding of key mathematical concepts and ideas so that these are consistent with current mathematical concepts in the field. Mason (Sfard et al. 1998) applauds these views and claims that for the conversations and discussions to be productive in mathematics academic learning a critical factor is the presence of the more competent 'other', who often would be the teacher. Most students, he argues, will not be able to identify the central and important mathematical ideas without guidance from an expert – the teacher. Additionally, he states that conversations and classroom discussions should not indiscriminately be considered as positive elements in the learning of mathematics. The learning potential will depend on *the quality* of the conversations; the support and commitment from the participating students, the level of mathematical knowledge and expert qualifications in the student group, not to mention the teacher's active role as a mathematical expert. Sfard et al. (1998) also stresses the important role that the teacher has as a director of the mathematical conversations. She criticizes what she calls a naive and unabashed faith in the value of discussions as learning tools in mathematics, and formulates the following warning:

> There are many ways to turn classroom discussion or group work into a great supplier of learning opportunities; there are even more ways to turn them into a waste of time, or worse than that – into a barrier to learning (Sfard et al. 1998, p. 50).

Initiating and orchestrating productive mathematical discussions is an extremely demanding and complex task for teachers. Sfard points out that teachers especially run the risk of failing if they take it for granted that the students know how to mathematically describe their opinions, ideas, and intentions to others. This is not a skill that students necessarily possess, she argues, but a competence they may develop through adequate training in the classroom.

9.3 The Ability to Talk in and About Math: Required Communicative Skills

If the learning of mathematics is defined as participation in and familiarity with discourses within a particular mathematical practice (i.e., in the classroom), the insights into the regulations of such conversations – what Sfard (2000) calls the understanding of the meta-discursive rules of the discourse – are central in analyzing the learning that takes place. According to Sfard, the discursive rules regulate both the structure and the content of the conversations and also the relationships between those that participate in the conversations. Sfard and Kieran (2001) distinguish between *object-level rules* and *meta-level rules* as two different dimensions in their analysis of classroom discourse. While the former regulates the various cognitive elements that are used to solve a particular math problem, i.e., the mathematical content dimension, the latter are related to aspects of the social interaction, such as turn-taking and negotiations of social positions. In other words, meta-level rules refer to the general discursive rules that regulate the flow of the conversation, while object-level rules regulate the content of the conversation (Sfard 2000).

Sfard and Kieran (2001) have developed these analytical concepts on the basis of longitudinal observations and analyses of pupil collaboration and student dialogues. In these analyses they show that discussions and conversations as learning tools can put students under great pressure, because they are forced to deal with both of these communicative sets of rules simultaneously. This can be quite strenuous, they argue, and students tend to be easily distracted, meaning that they will be mostly occupied with the non-mathematical aspects of the situation. Sfard and Kieran maintain that for student conversations to function as effective learning tools for the development of mathematical proficiency, participants must be directed to focus primarily on the aspects of the mathematics tasks related to the object-level rules, i.e., to concentrate on the content dimension of the conversation. Sfard and Kieran thus challenge the idea that student collaboration and group/couple conversations per se will necessarily have positive learning effects. They argue that there are certain requirements for the content dimension of the discussion that have to be met in order for learning to take place. If these are ignored, the meta-discursive aspects of these types of conversations will easily get too much attention. This will reduce the learning potential of the situation and also the productive use of the 'other'; the more competent expert. In stating this they are critical of the Vygotskian doctrine that collaborating with a more knowledgeable 'other' necessarily leads to increased learning.

Franke et al. (2007) point out that the teacher's active and conscious use of *re-voicing* can help increase student learning during mathematical conversations. Re-voicing is when the teacher repeats or reformulates a comment from a student, with the intention of enhancing or clarifying a mathematical idea. For example, re-voicing allows the teacher to substitute everyday words for a more precise mathematical vocabulary or vice versa. Through re-voicing the teacher can also consciously re-direct the discussion, to ensure that it remains mathematically relevant. Re-voicing also provides opportunities for teachers to communicate new mathematical concepts, ideas and ways of thinking, and link these to ideas that the students have communicated. As such, re-voicing can function as an important tool for teachers in keeping mathematical discussions in the classroom relevant to the wider mathematical academic community. In this way the teacher will take the role of the math expert, or the more competent 'other'.

The *quality of the tasks* will also have a major impact on the learning potential of students' conversations and discussions, as it will greatly affect the content of the discussions the students will be involved in. Silver and Smith (1996) define the quality of mathematical tasks in terms of the extent to which they are able to engage students in thinking and reasoning around key mathematical ideas. An important quality criterion is therefore that the tasks can be solved in several ways, which means that they allow for different mathematical representations. Students must be given opportunities to make guesses, interpret different ideas and formulate and justify their own solutions to the actual problems. Stigler, Gallimore and Hiebert (2000) relate the quality of mathematical tasks to their mathematical importance and to the extent to which the tasks are related to the knowledge students already possess. Sfard and Kieran (2001) emphasize focus and coherence as two important criteria for assessing the quality of mathematical conversations. They claim that tasks should be designed in a way that helps the students retain these qualities in their conversations. Tasks that are formulated too rigorously and are thematically narrow can prevent productive exchanges of opinions, Sfard (2000) argues. On the other hand, tasks that are too open and wide in scope will require mathematical skills that students often do not possess, which will easily lead to unfocused discussions.

As this review shows, there is widespread agreement among many researchers within mathematics education that it is very important to develop teaching sequences that can contribute to discursive activities in mathematics classrooms. Inspired by Sfard and colleagues' distinction between object-level rules and meta-level rules, we will use *object-level skills* and *discourse-level skills* as key analytical concepts in our discussion of conversations as learning tools in mathematics. *Object-level skills* are here understood as the ability to talk in and about mathematics, while *discourse-level skills* refer to general communicative skills; i.e., negotiation, positioning, regulation of turn-taking and division of labor within social groups. The role of the more competent class members, and especially the teacher's role as an expert and an orchestrator of classroom conversations, and the quality of the tasks, will also be drawn upon in the analysis. First of all, however, we will briefly present the sampling method and empirical data from the current PISA+ Study on which we have based our analysis.

9.4 Data Sources and Methods

The empirical data used in this analysis is taken from one of the classes that participated in the PISA+ Study. The school was located in an area that can be characterized as ethnically homogenous and socio-economically middle class/upper middle class, and the class had 18 students, 11 girls and 7 boys. According to the teacher, the student proficiency level could be described as close to the average in relation to national standards. The teacher had qualified a few years earlier and had quite recently completed a 1 year course in mathematics education. By Norwegian standards, she would be considered as well qualified for teaching mathematics at this grade level.

In the actual lesson sequences that this analysis is based on, the teacher used newspapers as a source for the mathematical tasks the students were given. In this way she afforded the students opportunities to relate their mathematical discussions to real events. It should be emphasized that this was not a very typical occurrence in the mathematics lessons that were observed in the PISA+ Study. In the vast majority of the 38 video-filmed mathematics lessons in this study, the students spent a lot of time working on conventional exercises from the textbook (Klette et al. 2008; Bergem 2009). Therefore, the criteria for selecting the data material for our analysis from this teaching sequence is not that it is particularly representative, but that it is very interesting in relation to ongoing contemporary discussions among researchers within mathematics education. Undoubtedly, our chosen teacher used working methods that are highly recommended in contemporary pedagogical and didactical literature within this field.

9.4.1 The Instructional Sequence

In the first lesson of this sequence, the teacher took a few minutes to give the students an explanation of and instructions about the work to be done. The actual tasks the students were given consisted of a mixture of open and more structured problems. All the tasks were related in some way to information given in newspapers. The general information on the sheet the students were given was formulated as follows:

Tasks for Group Work (Pairs)
Do your best to answer these tasks. You are to discuss some of these problems in both mathematics class and social studies class this week. When you're done; remember to put the tasks and the answers in your blue workbook.

Task 1
We live in an information age, and very often numbers and mathematics are used to inform us. In our democracy it is important that everybody can understand and evaluate information from different sources, for instance newspapers, TV, journals, commercials and advertising, political meetings and debates. Use the newspapers at school to find examples where numbers and mathematics are used for information purposes.

The students were told to work in pairs, and that for task 1 they should find two examples from one of the newspapers that were made available by the teacher. As can be seen, Task 1 was very open and unstructured. The students were to decide themselves what kind of examples they wanted to use, the requirement being that it should relate to how mathematical or statistical terms are used and expressed in the newspapers.

In task 2, students should consider and comment on the following four statistically related statements:

Task 2
When numbers, calculations and statistics are used, we easily believe that what is being said has to be true. Study the cases below. What kind of impact do you

think the numbers have on people? What kind of information is given? Give your comments and explain different interpretations of these cases.

– ***Task 2a***: *Henry (smoking in a macho way): "That smoking is dangerous is just a bunch of crap. My grandfather smoked two packs of cigarettes daily. He was never sick and passed away at 87."*
– ***Task 2b***: *The mean income in Hill County is 380550 NOK.*
– ***Task 2c***: *A pharmaceutical company has presented a study of the healing effect of a cold medicine. 80 % of the people that used this medicine recovered within a week. On the evidence of this study, the use of this medicine is recommended.*
– ***Task 2d***: *Big headline in the paper: "Tuberculosis doubles in 1 year". In the text below is added "this year six people got tuberculosis as compared with three last year."*

This stimulus material was selected by the teacher and, consequently, clearly structured and defined in advance. In the subsequent math lesson, the following day, the teacher led a whole class discussion in which the students' various solutions were discussed.

In the first lesson, two of the students in the class, here called Tom and Frank, were video-filmed. We also video-filmed the subsequent whole class discussion the day after. In addition, the two authors of this chapter were present as observers in both lessons. The empirical data material for our analysis will consist of the conversations between Tom and Frank in lesson 1, and the whole class discussion in lesson 2. In addition, we will refer to an interview with Tom and Frank held immediately after lesson 1, and a later interview conducted by the teacher.

9.5 Findings: Discussing Tasks: Where's the Mathematics?

During the interview with the two boys, Tom reported that he got grade four in mathematics, while Frank got a lower grade. The way they positioned themselves in their discussions in the observed lesson, showed that they were aware of these differences in their proficiency level. For example, Tom repeatedly had to interpret the tasks for Frank and explain to him what they were expected to do. On several occasions Frank also directly asked Tom for help and support. Still, it is fair to say that they both contributed constructively to the ongoing discussion, albeit to varying degrees. Here's an excerpt from their initial conversation:

Excerpt 1
(Tom reads silently from the task sheet.)

Tom: (Reads silently from the task-sheet)
Frank: That means that we are supposed to do what?
Tom: Wait a second. (Reads aloud) Well, I guess we have to go and get some newspapers.

After Tom was back with the newspapers, they hesitated a moment, then decided to get sheets to write their answers on.

Tom: I think maybe we should get sheets to write the answers on before we get started.
Frank: Yeah I write, you fetch. (Grabs the newspaper from Tom)
Tom: (A bit aggressively.) You can go and fetch it you don't understand anything anyway.
Frank: (laughs) Well that's true.

As can be seen in this episode, the boys negotiate between themselves about how to organize their work. Frank tries to take command, but this is rebuffed quite fiercely by Tom. With reference to Frank's low performance level, Tom claims the role of the leader, and Frank immediately accepts. Tom's leadership is not challenged by Frank at any stage later on in the group work.

After Tom and Frank had taken quite some time to read the task sheet and the newspapers, they eventually began to discuss what they should do. They decided to use a political poll presented as a pie chart in one of the newspapers as their first example of the use of numbers/statistics, but clearly had great difficulty understanding the information in the chart. The following is an excerpt of the conversation between them:

Excerpt 2

Frank: (lightly provocative, without trying to find an answer himself) And the answer is. ..
Tom: (gives Frank the newspaper, and exclaims a little irritated): Look here, then you will understand what to do!
Frank: (still provocative and uninterested.) The question is?
Tom: We're supposed to find examples from the newspaper!
Frank: Okay.
Tom: It's not that hard. And then we have to write down the answer. We are supposed to figure out the meaning and write down the answer.
Frank: What then? What is this called? (Points to a diagram in the paper)
Tom: We call that a pie-chart.
Frank: And bar-chart.
Tom: No, we will not use that.

After a brief attempt to interpret the pie chart, without having succeeded particularly well, the boys were interrupted by the teacher who asked if they needed more paper. After that the two boys continued to chat about non-school issues for a while. However, they spent some time drawing the pie chart on their sheets. Twenty minutes of the lesson had now passed. The boys had only to a small extent succeeded in applying relevant mathematical concepts in their discussion of the task. Up until this moment they had mostly used their general communicative skills or their *discourse level skills* in their conversation. However, the teacher then returned.

She told them to write down *how* the chart was used in the newspaper. This was of great help for the boys, which is reflected in the subsequent reply:

Excerpt 3

Tom: Let's write that Dagbladet (the newspaper) shows the size of the political parties by means of a pie-chart.

In this way, the teacher's intervention ensured that the students' *object-level skills* were activated. The students now succeeded in formulating a mathematically adequate and meaningful answer to this task. As illustrated in the above statement, but also later on in the lesson, Tom was willing to take the responsibility for their joint work. He was continually oriented towards producing results and several times stated that they had to get things written down on paper.

9.5.1 How to Secure the Mathematical Content of the Discussions

As their second example, the boys chose a football table from the sports pages in the newspaper. Tom suggested they should write that the table showed how many points the teams had gained and the number of goals scored and conceded. They both put this down on their sheets of paper. Frank expressed little interest in and a lack of understanding of football and league tables, so Tom had to give instructions and tell Frank exactly what he should write down. Mathematically, a football table must be considered a relatively uninteresting example of the application of statistics in newspapers. Additionally, it does not appear to be very mathematically challenging for 14 year old students to copy football league tables. Thus, in this episode too it was primarily the boys' *discourse level skills* that were applied and developed.

The students had now finished task 1. The teacher's input had allowed the students to succeed in formulating a relevant statistical answer to the first selected example, but the second illustration, the football league table, did not generate any kind of dialogue connected to the development of mathematical understanding and conceptual training of *object-level skills*.

The boys then started to work on task 2, which read as follows:

> When numbers, calculations and statistics are used, we easily believe that what is being said has to be true. Study the cases below. What kind of impact do you think the numbers have on people? What kind of information is given? Give your comments and explain different interpretations of these cases.

The first text was this:

- *Task 2a: Henry (smoking in a macho way): "That smoking is dangerous is just a bunch of crap. My grandfather smoked two packs of cigarettes daily. He was never sick and passed away at 87."*

The following dialogue then took place:

Excerpt 4

Tom: It's only something that is claimed, we don't know for sure it's like that.

Frank: Yeah, it's only claimed. It could be true though; there are people who smoke that don't... (Interrupted by Tom)

Tom: Yeah, but it's not. Smoking is no good anyway.

Frank: Anybody who smokes doesn't stay healthy, if they smoke a lot.

Tom: Let's write that then. (Both students start to write down this answer. After a few seconds Tom starts to read aloud what he is writing down): 'Some manage to smoke without getting cancer, but others don't'.

Frank: (Also reads aloud what he writes down): Let's say that 'the majority die of cancer'.

What characterizes this dialogue is that neither Tom nor Frank are able to connect their arguments to any kind of mathematical or statistical concepts. No statistical references are made, although the stimulus material clearly invites the students to apply their pre-knowledge of statistical contexts and concepts to the case discussion. As all the arguments are linked to health-related consequences of smoking, the dialogue appears quite irrelevant within a mathematical discourse. Again, it seems that it is only the students' *discourse-level skills* that are stimulated and trained. A major reason for this could be that the necessary mathematical skills are not present in this small group; at least they are not used or activated in relation to the actual tasks. This also illustrates, incidentally, one of the downsides of utilizing small groups in this kind of work. In a larger group of students, the possibility that someone may come up with mathematical relevant arguments is obviously greater.

9.5.2 Significance of the More Competent Other

The next statement Frank and Tom discussed, was the following:

– *Task 2d: Big headline in the paper: "Tuberculosis doubles in 1 year". In the text below is added "this year six people got tuberculosis as compared with three last year."*

Tom and Frank discussed what sort of comments they should give here, but neither of them managed to come up with any meaningful suggestions or strategies. The teacher came along, and Tom asked her for help. The dialogue went as follows:

Excerpt 5

Teacher: If you bought the paper one day, and this was the headline: "The number of cases of tuberculosis doubles", what would you think?

Tom: That many people die, that many people would get it, but then there are only six people, is that what you mean?

Frank: (very eager) There are only six people, but a great headline. You would think it was at least a hundred!

(Teacher smiles reassuringly and moves on.)

Through support from the teacher, the two boys' now understand the complexity of the newspaper headline, and this boosts their interest. The teacher's intervention and support has again stimulated the students' interest and led to an activation of their *object-level skills*. By giving a positive response to the students' statements, the teacher also signals that she expects the students to be able to critically interpret the issues presented in the media. She does not ask them to use advanced mathematical concepts in their explanations; the dialogue seems to have a relatively loose connection to mathematics, but she wants them to relate their comments to some statistically meaningful concepts. As can be seen in the above excerpt, the students' dialogue becomes more mathematically and statistically relevant after the teacher's intervention.

The students also worked with two other given examples, and the same pattern was repeated. Without the support of the teacher, the two students were only occasionally able to come up with arguments related to a mathematical discourse. Mostly the concepts they used and the statements they wrote down on paper had very little mathematical relevance. Therefore, we can conclude that the mathematical value of these types of tasks for our students was very unclear, especially when they were left to themselves to discuss the tasks. Consequently, it was predominantly the students' *discourse-level skills* that were developed in these situations. In order to succeed in making their discussion statistically relevant, the students needed the support of their teacher. When the teacher intervened and introduced a relevant mathematical perspective on the actual issues, the students were capable of relating their arguments to statistics. In these situations they were given the opportunity to develop their *object-level skills*. A challenge for teachers handling classrooms with a high number of students will often be to find enough time to provide the necessary support for each dyad/group of students.

9.5.3 How to Secure the Quality of Classroom Conversations

In the subsequent mathematics lesson, the following day, the teacher led a whole class discussion based on the students' answers to the newspaper tasks. The students pulled up their chairs and sat in a circle, and the conversation was held in a very open and inviting atmosphere. By positively accepting all kinds of answers, the teacher made sure that the threshold for participation was kept low, and nearly all students spoke during this lesson. However, even though the teacher accepted all answers, she gave particularly positive responses to mathematically relevant arguments from the students. She used re-voicing, the technique of repeating, clarifying and giving special attention to the most mathematically relevant answers, in which, for instance, mathematical concepts were used. By using the students' own formulations and sometimes adding to them, the teacher ensured the mathematical relevance of the whole class discussion. In doing this, she made sure that the students' *object-level skills* were stimulated and improved. As an illustration of how this was accomplished, a few situations from this lesson will be presented.

Example 1
In the first task, in which students were supposed to find instances of mathematically relevant material in the newspaper, it became clear that most students had chosen relatively uninteresting examples, such as page numbers, football tables and the like. The teacher did not make many comments on these examples. Some students, however, pointed to the use of different types of charts, and the teacher then responded with appreciative remarks. At the same time, she asked these students to explain what kind of charts were presented and how they were actually used in the newspapers. In this way, the students were led to understand that mathematical knowledge is relevant for the interpretation of a lot of the information presented in the media.

Example 2
The second task discussed, was the statement saying smoking is not harmful. Like Tom and Frank, several students came up with normative statements characterized by having little mathematical relevance. After having listened to some of these opinions, the teacher asked the students if it was acceptable to assess whether smoking was hazardous or not based on the information in this task. One student responded that only one person was cited in the article. Another student immediately followed up by saying that you have to use many more people to be able to say something definite about how dangerous smoking is. The teacher immediately gave very positive feedback to this student, and added that it is not possible to base general conclusions on such a small sample. Although statistical terms were scarcely used in the discussion of this task, the teacher, through leading questions and selective positive feedback, managed to direct the conversation to make it mathematically meaningful. In this way, the students were afforded an opportunity to participate in a relevant mathematical discussion, based on a concrete example from daily life.

Example 3
The class now continued discussing the third task, based on the following statement:

> A pharmaceutical company has presented a study of the healing effect of a cold medicine. 80 % of the people that used this medicine recovered within a week. Based on this study, the use of this medicine is recommended.

Left to themselves, Frank and Tom had the previous day been unable to relate their conversation around this statement to any mathematically relevant concept. In the current lesson several students made somewhat similar comments, relatively unconnected to mathematics. One student argued that one usually recovered anyway, even if you did not take any medicine. The teacher commented that this was probably correct, but then she asked the students if there was anything else they would have to know to be able to evaluate the ad's claims about the effectiveness of the medication. A student now responded that many people did not recover. The teacher nodded, but reiterated her question about other things one ought to know about this study. When no one answered, she continued to give them clues and hints about what she expected them to come up with. Here is the conversation that followed:

Excerpt 6

Teacher:	How much is 80 %?
Student 1:	8 out of 10
Teacher:	Or, 80 % can be a lot, can't it?
Student 2:	Yes
Teacher:	It depends on what? (With a smile on her face.) What do you guys think I am looking for?
Student 3:	If you ask 10 people and eight of them answer yes; then it is 80 %.
Teacher:	Sure, but if you ask a hundred? The more people you ask, the more you will have reasons to trust the survey. If you only ask a few persons, then you'll have a too weak basis for drawing any conclusions. Often in a survey there will be information about the number of people that are asked.

In this task, the teacher did not succeed in making the students come up with any mathematically significant comments. She got a correct answer to her first question, but little response to her follow-up probes and in the end she herself had to point to the lack of precise information in this text. It should, however, be noted that her probing questions were rather vague and somewhat difficult to interpret. The teacher seems to implicitly concede this by stating the question "*What do you guys think I am looking for*?" Regardless of this, the main point is that when no adequate input from the students was received, the teacher had to bring mathematical relevant arguments into the discussion. In this case these were related to sample size. As can be seen in excerpt 6, no precise statistical terms were presented, yet clearly the teacher led the discussion in a way that turned it into a more mathematically relevant discourse. She ensured that the students had the opportunity to improve their *object-level skills* and not only their *discourse level skills*.

All the other tasks the students had been working on the previous day were discussed in a similar way. In summarizing this sequence, which actually lasted only about 20 min, it could be said that the teacher played a very important role by always making sure that the conversation was kept on a mathematically relevant track. She achieved this by asking students relatively easy, but to-the-point questions and follow-up questions, by emphasizing good answers (*re-voicing*), and/or by herself introducing mathematical or statistical relevant concepts. Throughout this lesson sequence she provided the students with ample opportunities to formulate their own understanding of mathematical concepts. Furthermore, by creating an inclusive atmosphere, the threshold for participation was kept low and practically all the students gave their opinions during this session. Through the application of these instructional methods, the teacher made sure that the students got first-hand experience in how to take part in an academic discourse related to mathematics in a socially acceptable way. All the students were provided with opportunities to exercise both their *object-level skills* and their *discourse-level skills* through this teacher-led discussion.

9.6 Conclusion

Researchers emphasize that the teacher's ability to design, structure and lead productive learning situations is a key element for realizing the learning potential of oral tasks (Sfard et al. 1998; Cobb et al. 2000; Sfard and Kieran 2001). The teacher needs to have in-depth knowledge and insight into students' mathematical thinking and to be able to plan and design learning activities and assignments that support, stimulate and challenge students' mathematical reasoning and in that way develop their mathematical competence. However, another factor of importance is the composition of the student groups. Members of such groups need to have relevant mathematical knowledge in relation to the tasks they are asked to discuss. In our empirical material, the two students, when on their own, succeeded only to a small extent in formulating and proposing mathematically relevant arguments. It was mainly in the situations where they received teacher support that the two boys were able to link their reasoning to mathematics. In the whole class discussion also, the teacher's competence in leading the discussion stands out as a crucial factor. By actively directing and regulating the conversation in a way that secured both the academic content and broad participation, virtually all the students were trained to participate in a mathematics discussion. Although the same tasks were discussed in both lessons, the learning potential seems mainly to be realized in the second lesson. Structuring the tasks more tightly in the first lesson could perhaps have benefited the students' learning. If, for instance, some of the relevant statistical concepts had been provided, it would have made it easier for the students to relate their discussions to mathematics and they would have succeeded to a greater extent in developing their *object-level skills*. During whole class discussion, when the teacher is present all the time, it does not seem to be necessary to provide such conceptual structuring information. Here the teacher, through active monitoring of the discussion, will assist the students in providing relevant arguments and keeping the discussion on a mathematically relevant track.

A natural conclusion from our analysis is that giving mathematics assignments that consist of discussing everyday topics to small groups of students is a risky project. As illustrated by the excerpts from the first lesson sequence in our empirical material, the discussion may not lead to improvements in their object-level skills. An interesting topic for future research projects will therefore be to examine more closely how variation in group sizes, competence and tasks can affect the mathematical content of student conversations and discussions.

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Part III
Engagement Matters

Chapter 10
"I Prefer to Take One Subject a Day"

Students' Working Strategies During Independent Teaching Sessions

Ole K. Bergem

10.1 Introduction

Since the late sixties numerous initiatives have been introduced in order to reform classroom practices in mathematics (e.g. National Council of Teachers of Mathematics 1989, 2000; KUF 1996; KD 2006, 2007). A common denominator for many of these reform initiatives has been to implement and stimulate more student-centered methods of learning and instruction and increase the opportunities for students' active engagement and participation in classroom mathematical activities. In Norway, the use of work plans is one of these reform initiatives. The work plan is a document that describes what the students are supposed to do and learn in different school subjects during a certain period of time, including hand-ins and both oral and written assignments (Klette 2007). Thus, work plans are supposed to inform the students about topics to be covered, learning goals, assignments, degrees of student participation and forms of assessment. From a pedagogical point of view a work plan is a tool that makes it possible to differentiate between the students with regard to time, pace, progression, content, localisation, and individual/group activities (Moen 2004). The use of work plans has largely emerged from the field of practice, and aims at providing the students with more opportunities for active and autonomous learning (Carlgren 2005; Carlgren et al. 2006; Klette 2007). Using work plans can thus be considered an attempt to comply with the requirements in the Norwegian curriculum related to differentiation, self-regulated learning, student participation, and individually adapted teaching/learning (Klette 2007).

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In all the classrooms that were videotaped in the PISA+ Video Study, work plans were being used. One consequence of the use of work plans is that the students can choose between a variety of working strategies in mathematics, such as where and when to do their assignments and generally how much time to devote to doing school related tasks. Observations of classroom processes and excerpts from student interviews conducted in the PISA+ Video Study are used as documentation of what kind of working strategies different students seemed to prefer. A key issue in this chapter is to discuss what kind of implications the students' preferred choices apparently have for their opportunities to learn mathematics. This issue will be debated in light of social constructivist (Voigt 1994) and social cultural learning theories (Sfard 2000, 2006; Van Oers 2006), and also with reference to findings from the field of cognitive psychology related to questions of how mathematics should be studied in order to optimize learning outcomes (Willingham 2002; Rohrer and Taylor 2006; Rohrer and Pashler 2007).

10.1.1 The Use of Work Plans in Norwegian Classrooms: Background and Assumptions

As an introduction to the analyses of work plans, some important features of the school systems in Scandinavia, including Norway, will be described. The comprehensive school systems in these countries have largely the same characteristics, being unified and unstreamed and giving the highest priority to providing the same learning opportunities for all students. Individualized teaching methods have been advocated as a means to accomplish differentiation and stimulate self-regulatory learning within these unstreamed school systems, and individualized methods of working have steadily increased in importance within Swedish and Norwegian compulsory school during the last few decades (Carlgren et al. 2006).

Work plans were introduced in Norwegian classrooms during the late 1980s/early 1990s as a way of coping with the demands related to individual differentiation and students' self-regulatory learning (Dalland and Klette 2012). Their use has steadily increased, up to the point where now almost all Norwegian classes, in primary and lower secondary schools, use work plans as primary planning tools (Klette 2003; Bergem and Dalland 2010). In all of the six schools included in the current study the teachers used work plans to organize student activity. There is a corresponding way of organizing student activity in Sweden termed 'own work' (Carlgren 1988; Österlind 1998, 2005). Even though the current analysis is based solely on work plans as used in Norwegian classrooms – and there admittedly are some differences between work plans and 'own work' – reference will be made to Swedish research on 'own work' when this seems relevant to the discussion.

In the PISA+ sample of classrooms, students were given new work plans every second or third week. The work plans were organized by subject, often one subject a page. Figure 10.1 shows how the mathematics part of a work plan was presented for the students in one of the classes in the PISA+ study.

Mathematics		
Theme: Equations		
Goal 1 Know what the equal sign, =, signifies. Know what is meant with an 'unknown'. Be able to solve equations with one x-term. Manage to check the answer	**Goal 2** Same goals as 1 + Solve equations with more than one x-term. Solve equations where x is multiplied with a number. Manage to solve simple word problems using equations.	**Goal 3** Same goals as goal 1 and 2 + Solve equations where x is divided with a number.
<u>Working instructions :</u> Everybody must: enter the schools homepages, and click on *student*, then on *repetitions and short explanations*, then go to ***algebra,*** read everything about the 7 first themes to the left. Use these pages to achieve the goals.		
Goal 1 **Do the following exercises:** 1.2 a,b – 1.3 a,c,e, – 1.5 a,c,f – 1.6a,c,e – 1.26 a,b,c,d,e,f –	**Goal 2** **Do the following exercises:** 1.2 a,b –1.5 b,d,f – 1.7 a,c,e – 1.57 d,e – 1,58 –	**Goal 3** **Do the following exercises:** 1.2 a,b – 1.6 b,d,f – 1.8 a,d,e – 1.11 a,b,c – 1.12 d,e,f – 1.77 a,b,c,d – 1.80 – 1.88 Try some of the word problems on the pages 37 – 38 – 39.

Fig. 10.1 A work plan in mathematics for one of the classes participating in the PISA+ video study (Translation by the author)

As can be seen from Fig. 10.1, differentiation is achieved by offering the students three different levels of difficulty, namely Goal 1, Goal 2 and Goal 3. There are clearly some issues about the wording and layout of the plan, but these will not be discussed in this chapter. It is, however, hoped that Fig. 10.1 will give the reader a general impression of what a work plan may look like.

10.2 Theoretical Perspectives

As indicated in the introduction, the work plan as a learning tool has its origins in ideas of individualized and differentiated learning and draws on a mixture of pedagogical progressivism (i.e. activity pedagogy) constructivist theories of learning, the integrated day concept from the UK (Taylor 1972), and ideas of self-regulated learning. In addition, Carlgren et al. (2006) claim that the introduction and growing popularity of work plans can be analysed in light of recent changes in education policies. They argue that educational thinking over the last two decades has been impregnated with ideas and concepts from economic theories and that the meaning and content of schooling seem to have been reframed so that the idea of the educated citizen has been replaced by the idea of each individual being responsible for their own learning outcomes.

How work plans paraphrase central elements in constructivist and social – cultural theories of learning and how the use of work plans seem to influence both teaching practices and consequently students' opportunities to learn mathematics will be briefly sketched out in the next section.

Researchers have argued that there are significant epistemic differences between various constructivists and socio-cultural learning theories (Lerman 1996; Waschescio 1998; Sfard 2006; Cobb 2007). However, a common trait is that they all assign importance to collaborative activities and classroom discussions in the learning of mathematics. Within radical constructivism, which has been severely criticized for its individualistic perspective on learning and for being unable to account for learning as a social phenomenon (Kilpatrick 1987; Lerman 1996), the collective activities in the mathematics classroom are considered important as a source of the individual, cognitive perturbations necessary for promoting mathematical learning. While social constructivism maintains that meanings are individually constructed and not shared, it also argues that through social negotiation, knowledge is *taken to be* shared (Jaworski 1994; Voigt 1994). Classroom discourses and small group interaction are considered central elements in stimulating and generating social negotiation (Yackel and Cobb 1996; Cobb et al. 2000). Finally, within socio-cultural theory, 'learning' is generally viewed as becoming a participant in a certain discourse, and 'discourse' is viewed as the totality of communicative activities practiced within a given community (Lave and Wenger 1991; Sfard 2000, 2006; Van Oers 2006). To participate in collective activities (i.e. communication) is regarded as a prerequisite for processes of learning to take place.

To sum up briefly, a common trait in dominant learning theories within mathematics education is that collective and collaborative activities are considered to be of major importance in the learning of mathematics. Such activities are viewed as fundamental for stimulating student learning in mathematics. Particularly within social – cultural theories it is claimed that students must be given the opportunity to actively participate in meaningful dialogues in order to be able to broaden their discursive mathematical repertoire.

10.2.1 Teaching and Students' Learning

Hiebert and Grouws (2007, p. 372) formulate the following definition of teaching:

> Teaching consists of classroom interactions among teachers and students around content directed toward facilitating students' achievement of learning goals.

They state that teaching is a system of interacting features rather than a collection of independent and interchangeable features. Consequently, the effect of any chosen particular feature is difficult to isolate because it is influenced by related and interacting features. This severely complicates the research process, and it is an important reason why researching teaching effectiveness in order to reach reliable and valid conclusions often seems nearly impossible (Creemers and Kyriakides 2006). Hiebert and Grouws (2007, p. 375) explain that the effects of teaching for instance will be mediated by students' thinking, that is:

> . . . their attentiveness during instruction, their interpretations of the teacher's presentation and of the tasks they are assigned, their entry knowledge and skills, and so on.

Furthermore, some variables may exert a stronger influence than others. It would seem that the use of work plans as an overall organizing tool in the mathematics classroom strongly mediates the effects of teaching, defined in accordance with the above quotation, and may thus be considered among the most influential variables in the observed mathematics classrooms in the sample.

10.2.2 Opportunity to Learn

Even though the study of the connection between teaching and learning outcomes in mathematics is methodologically difficult and complicated, Hiebert and Grouws (2007) identify some factors or constructs that they claim are quite well established through findings in various empirical educational studies. One of these research-based constructs that seems particularly relevant in the discussion of how work plans mediate the activity of students is commonly labelled 'opportunity to learn'. It simply means that the 'students learn best what they have the most opportunity to learn' (p. 378). Hiebert & Grouws explain that even though 'opportunity to learn' may seem to be quite an imprecise notion, it can be a powerful concept if traced carefully through its implications. It includes: ‘considerations of students’ entry knowledge, the nature and purpose of the tasks and activities, the likelihood of engagement, and so on’ (p. 379).

Hiebert & Grouws tie the concept ‘opportunity to learn’ to Vygotsky’s (1978) well-known concept of the ‘zone of proximal development’, the space within which learning can be expected, under supportive conditions, given the person’s current level of functioning. They claim that ‘opportunity to learn’ can be considered a concept that expresses these supportive conditions, which, according to Vygotsky, are a prerequisite for optimal learning outcomes.

A different perspective on how optimal learning outcomes can be secured is found within the field of cognitive psychology. An important issue discussed here is what kind of working strategies students should apply in order to prolong the retention period of the studied topics, and a key concept is labelled ‘the spacing effect’.

10.2.3 The Spacing Effect

Cepeda et al. (2006) claim that a general and primary goal in education is to teach in a way that makes students remember what they have learned over an extended period of time. This begs the question of what kind of working strategies does best secure this kind of learning. ‘The spacing effect’ is a concept that is central in the research connected to the investigation of this issue. It refers to the fact that long term recall of learned material seems to profit from learning episodes being separated temporarily, ‘spaced’ or ‘distributed’, instead of being contiguous in time, often called ‘massed’ (Moshe 1990; Naveh-Benjamin 1990). Willingham (2002) argues that the finding that distributing study time over several sessions leads to better recall of the information than using the same amount of study time in one session is a consistent and robust finding reported in various studies.

Originally research on this issue was limited to requiring the verbatim recall of atomized facts, but, based on a study including the understanding of mathematical concepts, Rohrer and Taylor (2006) claim that the benefits of distributed practice also extend to conceptual tasks. They report that findings from their own studies indicate that “. . . long term mathematics retention is better achieved when practice is distributed rather than massed” (Rohrer and Taylor 2006, p. 1214). In a later meta-study, Rohrer and Pashler (2010, p. 407) claim that: “Distributed learning across different days (instead of grouping learning episodes within a single day) greatly improves the amount of material retained for sizable periods of time.” A key point in relation to these findings is that distributed practice produces these benefits without requiring extra time for practice; it is the division of the specific and limited amount of time into separated learning episodes that seem to be essential in regard to achieving increased learning.

10.3 Findings and Results

In this section it will be argued that the work plan generates different student strategies for doing mathematics in school. Excerpts from student interviews will be used to illustrate this claim. Firstly, however, a short presentation of work plans and study lessons as organizing principles of student learning in the observed PISA+ classrooms, will be given.

10.3.1 The Work Plan as a Didactical Tool

As mentioned in the introduction, work plans were used as an organisational and didactical tool in all the six classes in the study. There were, however, both similarities and differences between the classes with regard to the content of the plans and the way they were used. These are some of the most relevant similarities and differences in relation to the theme in this chapter:

- The duration of a work plan period varied across classes from one to three weeks.
- In all the classes the content of the work plan in mathematics was decided by the mathematics teacher only. The students did not participate in developing the plan.
- The work plans were not individual, but did contain some sort of level differentiation, usually three. It was up to each student to decide which one of the three levels to follow, and they were allowed to choose different levels from one work plan period to another.
- The three levels would usually cover the same mathematical themes, but were differentiated either by the number of tasks connected to each level, by task difficulty, or by a combination of these two criteria.
- The work plan in three of the classes had explicit learning goals in mathematics. In two of the other classes the work plan did not have any learning goals at all, while in the last class the learning goals were very vaguely formulated.

10.3.2 Study/Guidance Lessons

Common to all the PISA+ classrooms was the practice of allocating time for the students to use individually on the work plan, but this was done in different ways. Three of the classrooms had a fixed number of separate study/guidance lessons on their weekly schedule. In these lessons the students were free to decide for themselves what to do and which subjects to attend. Most often this meant doing assignments from the work plan. The number of weekly study/guidance lessons varied from three to eight at these three schools. In five of the six classrooms, the classroom with eight study/guidance lessons being an exception, the students were given time during regular lessons to use on their work plan. Work plans, especially in combination with the use of study/guidance lessons described here, were meant to give the students the opportunity to regulate their own learning process by increasing their influence on how to organize and manage their own schoolwork.

10.3.3 Data Material and Data Sources

The following analysis draws on video recordings from mathematics lessons ($n = 38$) in six different classrooms, covering both whole class sessions ($n = 31$), study/guidance lessons ($n = 7$), student dyads ($n = 31$), and student interviews ($n = 61$). These video-stimulated interviews were conducted shortly after each mathematics lesson and were later transcribed verbatim. Additionally, field notes were taken from the whole class lessons, with a special focus on describing students' engagement and active participation in relation to discussions, group work and work on assignments. Furthermore, copies of lesson plans, work plans, student assignments and student work were obtained for each mathematics lesson. Thus, the empirical foundation for the current analysis is based on these five data sources. An overview of these is given in Table 10.1.

10.3.4 Three Different Strategies for Working with Mathematics

Observation of student behaviour during math lessons, especially the study/guidance lessons, revealed that different strategies were being used in relation to the handling of the assignments on the periodical work plan. This was to a large extent confirmed in the follow-up interviews ($n = 61$) through the students own explanations of how they strategically positioned themselves to this plan. Basically these strategies seem to fall into three categories:

Table 10.1 Data sources for the analysis of work plans in this chapter

		Quantity	Type of data
1	Video recording of whole class sessions	$n = 31$	Coded video data
2	Video recording of pairs of students	$n = 31$	Un-coded video data
3	Transcriptions of videotaped student interviews	$n = 61$	Written transcriptions
4	Field notes from lessons	$n = 31$	In writing
5	Copies of lesson plans, work plans, student assignments and student work		Printed copies

1. To postpone the work in mathematics to the end of the work plan period.
2. To finish the work in mathematics in one or two days at the beginning of the work plan period.
3. To apportion the work in mathematics throughout the work plan period.

As will be seen from the interview excerpts, the students' reasons for choosing these strategies varied quite a bit. Through selected excerpts from student interviews, some examples of the most typical lines of argumentation will be presented.

The different student strategies also seem to have certain consequences for structures of participation in the mathematics classroom. As such, they can be analysed in relation to particular and important aspects of the learning theories presented earlier in the chapter. Through presentation and analysis of empirical examples, it will be argued that the use of work plans in mathematics apparently makes it legitimate for students to choose working strategies that may reduce their opportunity to learn.

1. *The strategy of postponing the work in mathematics*

The first position is characterized by students who postpone working on mathematical assignments until the very end of the work plan period. At two of the schools in particular this was a strategy that the majority of the boys seemed to embrace. At these schools it was observed that while the majority of the girls were able to apportion their work, dispersing it throughout the whole work plan period, nearly all the boys waited until the end of the last week to complete their assignments. This happened despite this school having allocated a large part of the weekly schedule to study/guidance lessons. The strategy of postponing the work on the math assignments is illustrated in this excerpt from a student interview, (I is the interviewer and B is a male student):

I: But when you're doing the assignments on the work plan, do you try to make plans for the whole three week period, or do you try to get finished as fast as possible, or what?
B: I always end up doing everything at the end, normally.
I: So you do not work during the first two weeks?
B: No
I: But then you . . . ?
B: So I have to do everything in the last 2 days.

Through his statements in this interview the student reveals that he usually postpones his work in mathematics until the very end of the work plan period. As previously mentioned the choice of this strategy was especially widespread among boys. Besides being documented through the student interviews, this is confirmed by the notes from the classroom observations and the analysis of the video films from the mathematics lessons.

By regularly postponing their work on mathematics, in the way student B exemplifies in this interview, students reduce their chances of meaningfully participating in classroom discussions related to the actual mathematical themes raised during a work plan period. Participation in these kinds of discussions is considered to be of major importance in learning theories within the field of mathematics education (Cobb et al. 2000; Sfard 2000; Van Oers 2001). Consequently, this must be regarded as a working strategy that is far from optimal for the students' opportunity to learn mathematics.

Additionally, by constantly postponing their work in mathematics to the last 2 days of the work plan period, and generally devoting little time to struggling with their math assignments, these students run the risk of reducing their chances of achieving a deeper mathematical understanding of the issues being discussed during math lessons. Therefore, the development of their mathematical competence will probably not be as positively stimulated as it could have been if other strategic choices had been made.

2. *The strategy of completing the work in mathematics in a day or two at the beginning of a work plan period*

The second strategic positioning is the one in which the students try to complete their math assignments for the whole work plan period in just one or two days at the beginning of the period. In the interviews the students presented basically two reasons for choosing this strategy. The first one was connected to a declared wish to finish the math assignments as quickly as possible, because they were boring to work on. The second reason, articulated by other students in this group, was that since mathematics was their favourite subject, they just couldn't wait to work on the new assignments. Even though these stated reasons are very different, the consequences of both are quite similar; all the students in this group would finish their math assignments in just a couple of days at the beginning of the work plan period and do relatively little work on mathematics during the rest of the period. Below is an excerpt of an interview with two male students (I is the interviewer, B1 and B2 are the two students):

I: Do you try to finish right away (the assignments on the work plan), or do you try to disperse it over the two weeks, or how do you do it?
B1: No, I like to finish it first and then . . .
B2: Yes, I prefer to take one subject a day sort of.
I: Ok
B2: And finish it.
I: So then, . . . when do you do the math then?
B1: I usually start off with math.
B2: So do I.
I: You do? But when do you finish then? Do you finish during the first week?
B2: Yes
B1: After one or two days, or something like that.

Even though this second working strategy is different from the first strategy, described above, they apparently share some common features. In particular, both these strategies imply that the students are occupied with mathematics for a very short part of the work plan period, "one or two days", as student B1 states. Doing all the exercises listed on the work plan in one or two days, instead of continually working on mathematics over the whole work plan period, may seem practical to the students for their own purposes. However, in relation to the findings connected to the concept of the spacing effect presented above (Naveh-Benjamin 1990; Willingham 2002; Rohrer and Pashler 2010), cramming the work with mathematics into one or two sessions instead of distributing it over time is likely to be far from optimal. This choice of working strategy may moderate the students' learning opportunities in mathematics, specifically in relation to the issue of retention periods.

In contrast to the first strategy of delaying math assignments, the strategy of doing all the exercises at the beginning of a work plan period does not necessarily impede the students from participation in the ongoing discussions in the mathematics classroom. Doing all the math assignments at an early stage should give this group of students relevant knowledge for participation in classroom discussions. However, many students who chose this strategy stated that, as soon as they had completed the math assignments on the work plan, they expected to be given the opportunity to work on other subjects during mathematics lessons. This was often conceded by their teacher. As will be argued more rigorously later in this chapter, allowing the students to work on non-mathematical subjects during math class is not likely to stimulate them to participate in mathematically relevant discussions. On the contrary, by working on subjects other than mathematics, the chances are that these students will pay little attention to the mathematical issues raised during the lesson. In the excerpt below, two female students reveal their opinion on this issue (I is the interviewer and G1 and G2 are two female students):

G1: My boyfriend is in another class and he is a lot better than me in math. So, one day (this week) he was helping me with my math assignments and we decided to do them all.
I: And then you were finished early?
G1: Yes
I: But what are you planning on doing in the math lessons next week?
G1: Right (laughs). I don't know. I have lots of other subjects to attend to.
I: Which you can do during the math lessons.
G1: Yes.

Addressing the same issue in the same interview, the student G2 responds as follows:

I: You do all the mathematics assignments (on the work plan) in a couple of days?
G2: Yes
I: And the remaining time?
G2: Then I do other stuff, or just relax.
I: In math class?
G2: Yes, it's really annoying if the teacher asks me to do unnecessary exercises instead of letting me do what's on the work plan, which one needs to do.

As can be seen from G2's last statement, she is primarily concerned with completing all the assignments that are listed on the work plan. Thus, the work plan seems to define what she regards as important to do in the various school subjects. Additionally, she also states that she finds it reasonable that the teacher allows her to work on other subjects than mathematics during the math lesson. It should be mentioned that not all six teachers who were observed in this study allowed the students to be occupied with subjects other than math during math lessons, even if they had completed all the math exercises on the work plan. Some of the teachers handled this situation differently, for instance by demanding that the students should participate in classroom discussions, or alternatively, work on other relevant mathematical problems.

3. *The strategy of working on mathematics throughout the whole work plan period*

The third strategy chosen by students was to disperse the work throughout the period. Most of the students who consciously chose this strategy, and could account for it in the interviews, were high achievers. They were quite articulate in arguing that this was the best way of ensuring high grades. Many of them also had quite high ambitions for their future careers. As an illustration of this group, an excerpt from an interview with two high achieving girls will be presented (I is the interviewer and G1 and G2 are two female students):

I: When do you usually finish your math-assignments (for the work plan period)?
G1: It varies a lot, but usually halfway through the second week.
G2: Yes
G1: Yes, with math
I: Is it the same with you?
G2: Yes

It seems reasonable to conclude that the third strategy is the best way of ensuring that the students will continually work on mathematics during the entire work plan period. This way of distributing the work on mathematics over longer time intervals accords better with the working methods recommended by researchers involved in studies of the spacing effect (Naveh-Benjamin 1990; Willingham 2002; Rohrer and Pashler 2010).

Additionally, this third strategy would also be likely to increase the possibility of taking part in ongoing classroom discussions. Many of these discussions would take place as the teacher introduced new themes, and students who considered that they had 'finished' the work or were lagging behind might be less motivated to participate. This lack of motivation or engagement could, of course, just as well be considered a main reason for choosing strategies 1 or 2, and not a consequence of making this choice. However, what seems important to take into consideration is that using work plans makes it legitimate to choose working strategies that imply that the students will be less motivated to take part in relevant mathematical discourses. This is clearly an unforeseen consequence of using work plans and as such an issue that needs to be addressed by schools and teachers that apply this didactical tool.

10.4 Conclusions

One of the central ideas behind the prominent use of work plans in Norwegian lower secondary classrooms is to give students responsibility for making decisions related to their work at school. In this chapter, some of the unintended consequences of using work plans as a pedagogical and didactical tool in the mathematics classroom have been discussed.

Alexander (1995) claims that when subject matter knowledge within a domain is rather low and fragmented the learner is often motivated by situational interest, not by a profound and genuine interest in the domain in question. The student is then likely to use strategies that are inefficient. As has been pointed out, the use of work plans gives the students the opportunity to choose strategies that imply that they will only work with mathematics one or two days during a whole work plan period of two/three weeks. For these students the consequences seem to be that there is little sustained work in mathematics; it is all about completing a certain number of tasks and assignments. This is by no means regarded as an optimal way of working with mathematics; on the contrary, academic achievement in mathematics is often linked to cumulative processes of learning achieved through continued step-by-step learning opportunities (Weinert and Helmke 1995). It seems reasonable to claim that this view is supported by the previously presented findings from cognitive psychology; that learners profit from distributing their studies over time instead of cramming them into one session only (Willingham 2002; Rohrer and Pashler 2010). In the present study, it has been argued that the lack of continuity in many students’ work with mathematics may reduce these students’ opportunities to learn mathematics.

It should also be noted that when the students are afforded increased responsibility for their own learning processes, as exemplified by the use of work plans in the PISA+ classrooms, the teacher’s role unfortunately seems to become somewhat unclear. For instance, the teacher has to accept that many students choose working strategies that are likely to be far from optimal from a learning perspective. In negotiations overheard, and documented through the field notes taken by the researchers, students would argue that as long as they completed the assignments on the work plan the teacher could not ask for more. It seemed to be difficult for the teacher to come up with a valid opposing argument, except by emphasizing that generally it would be wise to put as much effort as possible into working on mathematics assignments.

New pedagogical tools that are introduced in the mathematics classroom, and for example include transferring responsibility from the teacher to the students, may have unintended consequences that affect groups of students differently. As described in the introduction, a central goal in the Norwegian curriculum is to provide the same learning opportunities for all students. From this perspective it is clearly undesirable that some student groups should be given reduced access to socially important mathematical knowledge and competence. Additional research about such important issues would complement our knowledge about the consequences of the use of work plans, and should eventually be used in a more comprehensive evaluation of this instructional tool.

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Chapter 11
"Mathematics Is My Favorite Subject!"

Variation in Instructional Practices Boosting Students' Attitudes Towards Mathematics

Ole K. Bergem

11.1 Introduction

Attitudes toward mathematics is a construct that has attracted a lot of interest in educational research, both in small-scale qualitative studies (Boaler 1998) and in large-scale international studies (Mullis et al. 2008; OECD 2010), as well as in comprehensive meta-analyses (Ma and Kishor 1997; Marzano 2003; Hattie 2009), and as a basis for theoretical discussions of mathematical belief structures (Goldin 2002). This interest is triggered by the assumption that there is a close relationship between affective factors, motivational factors and student proficiency in mathematics (Nardi and Steward 2003; Op't Eynde et al. 2001). Support for this supposition has been provided in national studies (Hensel and Stevens 1997), and also in large-scale international studies like PISA and TIMSS (Mullis et al. 2008; OECD 2010). An urgent challenge in educational research is therefore to discover and examine key factors that support the development in students of positive attitudes towards mathematics.

In this chapter, a construct labeled *instructional variation* will be developed and examined with the aim of analyzing its relationship to measures of student attitudes to mathematics. The analysis will be based on data from the PISA+ Video Study and the TIMSS 2007 Study. In each of these two studies, which have quite different designs, data about both instruction and student attitudes were collected. PISA+ provides video data of mathematics lessons that, through coding, can be used to examine the degree of instructional variation, and interview data that gives information about students' attitudes to mathematics. One important instrument in the TIMSS Study design is the Student Questionnaire. Answers to some of

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the propositions and questions that are formulated in this Questionnaire afford information about students' attitudes to mathematics while others provide data about various aspects and qualities of instruction, for example, the frequency of certain activities taking place during mathematics lessons. Based on the above-mentioned data sources, the two constructs *student attitudes to mathematics* and *instructional variation* have been developed and correlations between these constructs have been analyzed.

The research question being posed in this chapter is the following:

How does instructional variation influence students' attitudes towards mathematics?

11.2 Theoretical Perspectives and Analytical Framework

Many definitions of the concept of 'attitudes' are found in the research literature (Leder and Forgasz 2002), including, among others, "the degree of positive or negative affect associated with some psychological object" (Edwards 1957, p. 2) and "moderately stable predispositions towards ways of feeling in classes of situations, involving a balance of affect and cognition" (Goldin 2002). In this chapter, following the above definition by Edwards, 'attitudes towards mathematics' will be understood as 'the degree of positive or negative affect associated with mathematics, as expressed by individual students through questionnaires or interviews'.

Attitudes are frequently linked to other psychological concepts, such as emotions, beliefs, values and motivation. Regarding the relationship between student motivation and student achievement, both Marzano (2003) and Hattie (2009) claim that multiple studies provide strong support for a positive impact of motivation on learning. Motivational factors seem to be most closely linked to achievement at the lower secondary school level (Guthrie and Wigfield 2000). In spite of this, it has been noted that in many cases research on instruction takes place without any particular consideration of affective issues (McLeud 1992), and that it is important to include these aspects in studies of teaching and learning. As mentioned in the introduction, PISA and TIMSS have devoted particular attention to this topic, (i.e. the relationship between motivation and achievement) and the student questionnaires applied in these two studies include various propositions about attitudes towards mathematics. One robust finding is that even if there are relatively large variations between different nations in how students rate their attitudes towards mathematics on a Likert scale, a positive correlation between such self-reported attitudes and achievement is found in practically all participating countries (Mullis et al. 2008; OECD 2010). While such a positive correlation does not establish a clear cause – effect relationship between attitudes and achievement, it is interpreted as supporting the supposition that attitudes positively influence achievement.

One approach to research on student attitudes has been to investigate how students themselves experience the various kinds of mathematics classroom teaching they are exposed to (Schiefele and Csikszentmihalyi 1994; Lee and

Johnston-Wilder 2013). Several studies have revealed that mathematics instruction is often quite conventional, consisting mainly of direct teaching, review and practice of routine mathematical skills (Stodolsky 1988; Stiegler and Hiebert 1999; Rowan et al. 2004; Klette et al. 2014). Such a monotonous approach to mathematics teaching has given the subject a reputation for being dull and boring (Boaler 1998). In study designs including interviews, this is often conveyed by students when questions about their views of mathematics are raised (Nardi and Steward 2003; Lee and Johnston-Wilder 2013).

Another approach to research on motivational factors and achievement has been to study this theme in relation to aspects of *teaching quality*. Operationalizing teaching quality is challenging and has been done in various ways in educational studies within mathematics, i.e. as ‘time on task’ (Berliner 1987), variation in content coverage (Rowan et al. 2004), the use of higher order questioning (Kilpatrick et al. 2001; Ball et al. 2009), the quality of instructional conversations (Cobb et al. 2000; Sfard 2000) or more generally by contrasting the use of reform-based instructional methods to traditional or conventional teaching methods, i.e. ‘direct teaching’, review and practice of routine mathematical skills (Boaler 2002). One aspect of teaching quality, related to classroom management, has been labeled ‘supportive climate’ (Seidel and Shavelson 2007) and is operationalized as managing classroom procedures to create an environment of respect and rapport. In a bi-national, video-based classroom study conducted in Germany and Switzerland (Lipowsky et al. 2009), using pre- and post-tests, one of the main findings was that a supportive climate moderated the relationship between mathematics-related interest and mathematics achievement. The more supportive the observers rated the classroom climate to be, the stronger was the relationship between mathematics-related interest and achievement at the post-test.

An aspect of teaching quality that often is debated within mathematics education, and which is strongly recommended, is to vary the working methods applied in the classroom (Resnick and Harwell 2000; Kilpatrick et al. 2001; Boaler 2002). In studies using student interviews it is often reported that many students express the view that they would have preferred the mathematics lessons to be less monotonous and more varied (Boaler 2002; Nardi and Steward 2003). Nevertheless, few studies have included attempts to operationalize variation as an aspect of teaching quality and inquire into its effect on student attitudes. The main aim of this chapter is to address this question.

11.2.1 TIMSS 2007 STUDY: Constructs and Key Findings

In the TIMSS 2007 Questionnaire the students answered a multitude of questions aiming to measure different background variables assumed to influence student achievement. These questions covered a range of different issues. Only a few constructs are used in the TIMSS 2007 study, one of which is labeled *positive affect towards mathematics* (PATM). This construct will be used in the analysis presented in this chapter, but it is renamed *attitude towards mathematics* (ATM). The values of the response alternatives to each question have been modified and the construct values recalculated. This will be explained in the next section.

Another construct established in this chapter is labeled *instructional variation in mathematics* (IVM). It is calculated on the basis of a set of closely related questions in the eighth grade TIMSS 2007 Student Questionnaire, connected to the degree of instructional variation in the TIMSS mathematics classrooms. It should be mentioned that the computed values of the two TIMSS' constructs are based only on Norwegian eighth grade students' answers.

11.2.2 Attitude Towards Mathematics (ATM)

The value of the construct ATM was calculated on the basis of the students' answers ($N = 5{,}775$, Missing = 150) to the following three propositions:

- 8d: I like to learn math
- 8 g: Math is boring
- 8 h: I like math

In the TIMSS 2007 Questionnaire the students were asked to tick one of the following options:

- strongly agree (0)
- agree (1)
- disagree (2)
- strongly disagree (3)

The values in the parenthesis represents the score values used in the subsequent analysis. In addition the scores for items 8d and 8 h were reversed so that higher values represent positive attitudes. This means that the range of the construct value will be 0–9, where 9 indicates the most positive attitude towards mathematics and 0 the least positive.

When a construct is calculated on the basis of only three questions, one worries about the issue of 'construct underrepresentation', including whether all important aspects of the construct are adequately captured (Messick 1989), or the construct has low overall reliability. As for the issue of reliability, Cronbach's alpha for the construct is 0.88 – which is considered to indicate a high degree of reliability. Additionally, as this construct is taken directly from the TIMSS 2007 Study, and consequently must have been approved by the international psychometricians and pedagogical experts involved in the study, it is assumed that these three questions cover the key aspects of the construct as described.

11.2.3 Instructional Variation in Mathematics (IVM)

The second construct, IVM, was developed with the aim of calculating a value for the degree of variation in mathematics instruction in the Norwegian TIMSS 2007 classrooms. It was calculated on the basis of the student’s responses ($N = 5{,}366$, Missing = 559) to eight propositions in the TIMSS 2007 Student Questionnaire q. 10 related to experience of classroom instruction. The students were asked to indicate how often the different activities occurred, by checking one of the following options:

- every or almost every lesson (1)
- about half of the lessons (2)
- some lessons (3)
- never or almost never (4).

In the present analysis, the values given to the students’ answers were modified in order to develop the IVM construct on a homogenous scale (Bergem 2012). As a result of this modification, the range of the construct value is 0–8, where 8 indicates a high degree of instructional variation while successively lower values indicate lesser degrees of variation. (IVM: Cronbach’s alpha = 0.601. All eight variables function well within the construct.)

Two constructs have now been developed, one that measures students’ positive attitudes towards mathematics and one that measures instructional variation in the TIMSS 2007 eighth grade classrooms. The next step in the analysis is to aggregate the value of the two constructs and the student achievement scores to the classroom level. Such aggregate values at a classroom level are considered to provide more precise and robust measures for the analysis that follows, as they are based on all students’ answers and scores.

11.2.4 Correlations Between Student Achievement and the Developed Constructs

After having aggregated score values in mathematics to a classroom level ($n = 264$), correlations between achievement score and the constructs ATM and IVM were calculated. The correlation coefficients are presented in Table 11.1.

As can be seen in Table 11.1, there is a significant positive correlation between the aggregated student achievement score (SA) and ATM, but not between SA and IVM. Documenting a positive correlation between SA and ATM is not particularly remarkable, as this corresponds well with findings from other large-scale educational studies, i.e. PISA (OECD 2010). While no significant positive correlation between SA and IVM is found, there is a significant positive correlation between

Table 11.1 Correlation coefficients between achievement score, ATM and IVM (classroom level)

	ATM	IVM
Student achievement (SA)	0.27**	0.04
ATM		0.22**

**Correlation is significant at the 0.01 level the two constructs ATM and IVM. Correlations between different constructs should always be interpreted very cautiously. In this case, claiming that positive student attitudes towards mathematics (ATM) lead to higher levels of instructional variation (IVM) does not seem to make much sense. Therefore, it seems reasonable to argue that the correlation between these two constructs indicates that providing a greater variation in activities in the mathematics classroom influences students' attitudes towards mathematics positively. This interpretation of the correlation between the developed TIMSS constructs could be reformulated as a hypothesis, namely the following:

Hypothesis

Providing variation in instructional activities influences positively students' attitudes towards mathematics.

In the next section this hypothesis will be tested using the data collected in the PISA+ Video Study. As reported in previous chapters, the PISA+ data includes several hours of video recordings from mathematics classrooms ($n = 31$) and, in addition, interview data from a high number of students from the same classrooms ($n = 61$). The question now posed is the following:

Does the analysis of classroom video and interview data in the PISA+ Video Study offer support for the above hypothesis?

11.3 Method and Findings

All the videoed lessons in PISA+, in all three subjects, were first analyzed on the basis of a set of theory-based categories and codes developed by project members (Klette et al. 2005, 2008).[1] Later, subject-specific analyses were conducted with a different set of theory-based categories and codes, also developed within the project (Ødegaard and Arnesen 2006; Ødegaard et al. 2006). Some common categories and codes were, however, also used across the three subjects in this second level of analysis, the main rationale being that it would make it possible to compare subject profiles.

11.3.1 Coding Procedures

Encoding of video captures from the classrooms was done through the use of Videograph, a software program developed in Germany (Rimmele 2002). The

[1] See chapter 2 for a more comprehensive presentation of the code schemes.

Table 11.2 Applied codes under the main category teaching activities

Activity description	Code	Explanation
Review	RW	Teacher summarizes or asks questions about previous lessons’ themes.
Motivation/appetizer	MA	Teacher uses an artefact or an exciting problem to collectively motivate student interest in a new topic.
Teacher summary	TS	Teacher summarises the work done in the lesson.
Going over the homework	GH	Teacher rehearses homework.
Going over the ‘do now’	GN	Teacher attends to a common problem in the lesson.
Developing new, canonical knowledge	CK	New knowledge is developed.
Developing new practical skills	PS	Mathematical knowledge is applied to a practical problem.
Offer seatwork	OS	Students are doing seated work.

Table 11.3 Frequency of eight featured activities measured in minutes in the six PISA+ study classrooms

Class	Eight featured activities measured in minutes								Total min.	Number of activities observed for more than:	
	RW	MA	TS	GH	GN	CK	PS	OS		2 min	10 min
Class 1	4	1	0	0	0	24	0	84	113	3	2
Class 2	24	2	0	1	0	151	1	111	290	3	3
Class 4	16	4	11	7	64	48	4	65	219	8	5
Class 5	5	30	4	0	27	38	0	89	193	6	4
Class 6	48	0	0	1	8	3	0	80	140	4	2

coding was initially done continuously, meaning at 1-second intervals, but later this was transformed to 1-minute intervals in order to make the statistical and graphical presentation more lucid. When more than one activity took place within one specific minute, the 1-second code most frequently registered was assigned to that minute interval. It was assumed that resulting variations would equal out across the analysis and only to a small degree affect the final results of the analysis. One main category used in the subject-specific analysis of the mathematics lessons was called Teaching Activities. In Table 11.2, the codes that were used under this category are listed.

Based on these codes, an overview of the frequency of featured activities in five of the six PISA+ mathematics classrooms is presented in Table 11.3. As Classroom 3 was visited shortly after the start of the semester, in September, and repetition was the main activity, it is not included in the analysis.

In the last column of Table 11.3, called ‘number of activities observed’, the various activities that occurred for more than 2 or 10 min have been summed up. This provides an indication of the degree of variation in instructional activities within each classroom. As can be seen from the numbers in this last column, there are substantial differences between the classrooms in this respect. Regardless of whether 2 or 10 min observations were used as a unit of time for this calculation, there are more variations of activities in Classrooms 4 and 5 than in Classrooms 1, 2 and 6. Based on this finding, the classrooms will be clustered in two groups in the next step of the analysis, with Classrooms 1, 2 and 6 constituting Group LV (Low Variation) and Classrooms 4 and 5 forming Group HV (High Variation).

11.3.2 Interviews: Variations Across Classrooms

In each of the 31 video-captured mathematics lessons in the PISA+ Video Study two students were chosen as a focus group, which means that they were filmed with a close-up camera and carried separate microphones. Shortly after the end of a lesson these two students were interviewed together. The interviews ($n = 61$) were semi-structured, meaning that a prepared interview guide was followed, but with openings for students to elaborate on themes and issues they themselves chose to talk about. Two of the questions in the interview guide were the following:

1. *Do you like mathematics?*
2. *Why do you like/don't you like mathematics?*

As the reader may have noticed, the first of these two questions is closely related to two of the three questions constituting the ATM construct in TIMSS 2007. In addition, the second PISA+ question provides an opportunity for the students to give reasons for their stated attitude to mathematics. In the TIMSS 2007 Student Questionnaire, being part of a large-scale survey study, such an opportunity is not given. This is therefore an example of how small-scale studies can provide additional information about students' own views which extend and deepen our understanding of key findings from large-scale studies.

The students' answers to question 1 are presented in Table 11.4, sorted by Group LV or Group HV.

A striking aspect of the data presented in Table 11.4 is the large variation between the two groups in the percentage of students stating that they like/dislike mathematics. While the great majority of students in Group HV (Classrooms 4 and 5) state that they like mathematics, there is a high percentage of students in Group LV (Classrooms 1, 2 and 6) that do not like mathematics. How can we explain this substantial difference in student attitudes towards mathematics in these classrooms? Is it just coincidental or could it be related to specific factors? In the next section

Table 11.4 The number (percentage) of students who state that they like/dislike mathematics

Group (class)	Like mathematics	Do not like mathematics	Number of students interviewed ($n = 48$)[a]
LV (1,2,6)	10 (45 %)	13 (55 %)	23
HV (4,5)	23 (92 %)	2 (8 %)	25

[a] Thirteen students interviewed from classroom 3 are not included in this analysis

this question will be illuminated by a presentation of a sample of student answers to question 2 above: *Why do you like/don't you like mathematics?*

11.3.3 Interviews: Selection Criteria for Students That Are Cited

As can be seen from Table 11.4, 48 students (23 + 25) were interviewed about mathematics lessons in the classes constituting Groups LV and HV. Excerpts from interviews with three students from Group LV (one from each of the three classrooms), and three students from Group HV are presented below. The most important selection criterion was that these students argued along lines that were representative for a larger group of students, i.e. their statements are quite typical. However, there is a second selection criterion that needs to be explained. Due to the large difference in the ratio of liking to disliking mathematics between the two groups, the main focus of interest was to investigate reasons for this disparity. Students expressing negative attitudes to mathematics have therefore been grossly oversampled in Group LV, such that all the three students selected from this group conveyed negative attitudes towards mathematics. As such they represent only the 55 % of the students articulating a dislike of mathematics and not the total student group. In Group HV, on the other hand, 92 % of the students expressed positive attitudes towards mathematics, and the three students cited from this group were selected from this "positive" section.

A final remark is needed about the grade levels referred to in some of the interview excerpts. In Norwegian lower secondary schools the grading goes from 1 to 6, comparable to the letter system A – F used in many English-speaking countries. Grades 6 and 5 constitute the upper levels (A and B) and are given to students considered to be highly competent in the field being tested. Grades 4 and 3 constitute an intermediate level (C and D), while 2 and 1 (E and F) are low grades, indicating a serious lack of knowledge and competence.

11.3.4 Interviews: Group LV (Low Variation)

Generally, many of the students interviewed in Group LV complained about monotonous lessons in mathematics. These were both high achievers and weaker students. The selected excerpts from the three student interviews presented highlight a quite widespread opinion among students in Group LV.

Interview 1_Classroom 1

I: Do you like math?

S1: Not really. It's pretty boring.

I: You find it boring?

S1: Yes . . .
I: But why do you find it boring?
S1: There is a lot of work with traditional tasks. It is not really practical.
I: No . . .
S1: I like doing practical tasks best.
I: Are you good at math?
S1: Yes I got like 5 . . . or 5 minus on my grade card.

Statements from quite a strong student (Classroom 1) are presented in Interview 1. His main reason for disliking mathematics is that he misses tasks and exercises that are related to practical issues. He also claims that a majority of the exercises the students are doing in the classroom are quite traditional, indicating that there is a lack of variation. This line of argument is followed up in the next interview, Interview 2.

Interview 2_Classroom 2

I: Do you like math?
S2: No
I: Why don't you like it, or . . . What is it that makes you not like it?
S2: It is a boring subject.
I: What is it that makes it boring?
S2: It's okay when one understands it, last fall it was okay, because then we worked on equations. I got a 5 on the test we had, which was great. But otherwise it is pretty boring; at least now, now it's just the same stuff over and over again. We have to draw large tables and work endlessly on each single task.

The student from Classroom 2 also complains about mathematics being boring because "*it's just the same stuff over and over again*", clearly indicating a lack of variation in student activities in mathematics lessons.

It should be noted that both students being cited in these two interviews are strong students, since they report that they get grade 5 in mathematics. As there are usually high positive correlations between achievement measures and positive attitudes to mathematics, their negative attitude to mathematics should be all the more concerning.

The student in Interview 3 also argues that his main reason for disliking mathematics is the lack of variation in the tasks given. He explains this in quite a colorful way: "*If we do a task five times, it's ok, but when we do the same kind of task 70 times . . . It's a bit too much!*"

Interview 3_Classroom 6

I: But do you like it?
S3: No, it's a little bit boring because we are going through the same tasks over and over again. So, I'm just tired of it.
I: You think it's boring?
S3: Yes, if we do a task five times, its fine, but when we do the same kind of task 70 times . . . It's a bit too much.

I: But how do you think it could have been made more interesting and exciting?
S3: A little less of each kind of task. Then it would have been a little more varied.

In his last statement, Student 3 explicitly argues that more variation in exercises given would have made mathematics more interesting and exciting. In another part of this interview, the student revealed that he got high grades in mathematics.

11.3.5 Interviews: Group HV (High Variation)

As shown in Table 11.4, as many as 92 % of the students in Classrooms 4 and 5 expressed positive attitudes to mathematics in the interviews. Several of these students emphasized the important role played by the teacher in their attitude to the subject. The quotes presented below are therefore to a large degree representative of the key opinions expressed by Group HV students.

Interview 4_Classroom 4
I: Do you like math?
S4: I don't like stuff like ... lengths and measurements.
I: Why don't you like that?
S4: Well, I just think it's difficult.
I: Ok, you just think it is hard? But what is it that makes you like other parts of the subject?
S4: It is the way Lisa (the teacher) demonstrates it, the way she does it. That's what I enjoy.
I: Yes.
S4: Like, from seventh through eighth grade, in primary school, math was no fun at all because we did the same stuff over and over again. But now we do different things and it's a lot of fun.

As can be seen in Interview 4, the student first states his dislike of certain parts of the mathematics curricula. However, after being prompted to describe his reasons for liking other mathematical themes, the student points to the teacher and the way she organizes the activities in the classroom. Specifically he argues that an important reason for his positive attitude to mathematics is the variation in activities that the teacher provides: "*...we do different things and it's a lot of fun*". Interestingly the student emphasizes his point of view by contrasting this to his experiences in previous years, when "*math was no fun at all because we did the same stuff over and over again*".

Although expressed a bit differently, the student in Interview 5 argues along similar lines. She states that mathematics is her favorite subject due to the fact that: "*...we learn something new all the time*". A plausible interpretation of this statement seems to be that the teacher manages to stimulate her interest in the subject by varying the activities used in the classroom.

Interview 5_Classroom 4

I: Do you like math?

S5: Yes, it's my favorite subject.

I: It's your favorite subject? Well, what is it that makes you enjoy the subject?

S5: I think it's interesting and I think we learn something new all the time.

The next interview is from Classroom 5. Many of the students in this classroom expressed high satisfaction with their teacher and the way he presented the mathematics, organized the classroom activities and answered their questions. A central element in the construct "supportive climate" (Seidel and Shavelson 2007) is a positive teacher – student relationship, and the interview data from this class indicate that the teacher succeeded in establishing this kind of climate. Here are excerpts from one student interview from this classroom:

Interview 6_Classroom 5

I: You've already stated that you like mathematics. What is it that makes you like it?

S7: I think it is a lot of fun when I succeed and when I see patterns and stuff.

(A little later in the interview)

I: What is it that makes one good at math, or makes you become good at math?

S8: One has to practice.

S7: Yes, one must practice, and that one thinks it is enjoyable.

S7: And that we have …, it has a lot to do with the teacher as well, how he organises the lessons. Tom (the teacher) does it in a way that makes me enjoy doing mathematics, so …

As can be seen from the student statements in Interview 6, the teacher is assigned a key role for the interviewees' positive attitudes to mathematics. From the teacher's perspective, the students' description of their teacher is framed very favorably. Although their formulations of what exactly their teacher does are not very precise, they indicate that he organizes the activities in the mathematics lessons in a way that makes the students enjoy the subject. In other words, he manages to create a "supportive climate" for doing mathematics.

11.4 Discussion

Increasing students' learning opportunities is often being seen as one of the most important overarching aims in mathematics education (Hiebert and Grouws 2007) and several factors may contribute to success in this regard. Lee et al. (2013) claim that if mathematics is considered to be difficult to master, then it is particularly important that the learners develop a: "…*positive adaptive stance to mathematics such that it will allow them to continue learning despite barriers and difficulties*" (p. 2). This view gathers support from robust findings in quantitative educational studies, where students' attitudes to mathematics are repeatedly found to be positively correlated to achievement (Marzano 2003; Hattie 2009; OECD 2010). But how can a *positive adaptive stance* to mathematics be stimulated and cultivated? A major aim of this chapter has been to make a contribution to this discussion by developing and analyzing the construct "instructional variation" and investigate how it relates to students self-reported attitudes. This analysis, combining data/findings from the TIMSS 2007 Study and the PISA+ Video Study, indicates that increased levels of instructional variation can positively stimulate student attitudes to mathematics, a finding that corresponds well with reports from other studies. In a recently published UK study (Lee and Johnston-Wilder 2013) investigating innovative ways of learning mathematics in secondary level classrooms, and involving students as co-researchers, one finding was that the structure of the lessons was important. Students stated that they did not want to sit still for too long, feeling bored, and that they did not do well in "*an environment where the work is boring and repetitive*" (p. 10). The students emphasized the importance of variation in keeping them motivated and interested in mathematics.

Even though our knowledge about high quality teaching practices in mathematics is quite extensive, and founded on empirically solid studies (Kilpatrick et al. 2001), described practices (Boaler and Humphrey 2005), extensive reviews (OECD 2005; Timperley and Alton-Lee 2008), and meta-studies (Hattie 2009), we still need to increase our understanding of how specific elements of a teacher's repertoire can be combined in order to optimize students' opportunities to learn. This does not mean that future teaching should be reduced simply to following a recipe, but rather that teaching as a profession should be research based and that we need to broaden our knowledge of which methods of instruction work better than others. If instructional variation is considered to be one of the most important and valuable factors in stimulating students' positive attitudes to mathematics, it is crucial to take this into consideration when developing in-service courses for professional development and generally when designing programs within teacher education.

Finally, it is important that promising innovative teaching methods, which can contribute to a larger degree of instructional variation, are given more attention as research objectives within the field of mathematics education, as the need to revitalize teaching and extend the repertoire of classroom activities appears to be a particularly big challenge for this subject.

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Chapter 12
Teacher Commitments: Love and Duty in Science Education

Marianne Ødegaard

A teacher was teaching a science lesson about electricity, where the class were doing some practical work on electrical circuits. The students were working in groups. One group of girls was not cooperating, so the teacher was trying to motivate them to work together; one group was trying to get the teachers' attention because they needed a new light bulb, so the teacher replied: "I'll get it in a minute!"; and suddenly a boy in the third group turns off the lights so only the circuit light bulbs light up the room. "Oh, it's like Christmas!" The teacher smiles and tells the student to put on the lights again, as he turns back to the female student to continue the discussion of the different consequences of serial and parallel connections. Suddenly a student proclaims: "I need a new notebook!"; "Me too," another adds. So, after leaving the discussion to the girls group, and giving group two a light bulb, the teacher decides to leave the room to get the books. Out in the hallway, he sees the school janitor, screwing a screw, one screw, into the wall… "We sure have different jobs."

12.1 Introduction

What makes teachers stay and work in such complex working situations? What are the teachers' commitments? The example above reflects a teacher's different considerations during a science lesson: How to offer insight into and knowledge of science and nature? How to offer students a useful and individually adapted education? The meaning making processes offered to students depend on the teachers'

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emphasis when navigating between sometimes contradicting commitments. The present study focuses on the teachers' perspective; their reflections, dilemmas, and implementation of meaning making activities. It seeks to reveal their professional and social commitments, and how contradictions within and between these commitments influence their teaching. Through classroom videos and video-initiated interviews we have had a unique opportunity to capture moments of teaching and learning and have teachers reflect upon them.

This study concentrates on the interviews with the science teachers involved in the PISA+ Study.

12.1.1 Science Education: Perspectives

Based on the Vygotskian perspective, the use of language in a social context is of crucial importance for science education. Learning science is learning to talk science, not only understanding science concepts but also learning to use structures and features of the scientific language. (Lemke 1990; Mortimer and Scott 2003) Modes of communication are a natural part of this picture. A tension between authoritative and dialogic discourse is a fundamental characteristic of meaning making interaction in science lessons. Scott et al. (2006) suggest that dialogic exchanges should be followed by authoritative interventions to develop the canonical scientific view, and the authoritative introduction of new ideas should be followed by the opportunity for dialogic application and exploration of those ideas. Engle and Conant (2002) imply that in order to foster productive disciplinary engagement students must be given authority to address subject matter problems, and they must be held accountable for their intellectual work.

The idea that inquiry-based science teaching is suitable for guiding and illuminating students' understanding of scientific processes and concepts (Keys and Bryan 2001) is well known in the science education research community, but perhaps not among Norwegian teachers. Two central features of this teaching strategy are inquiry into authentic questions generated from student experiences, and practical activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (Andersen 2007).

These perspectives influence the analyses and discussions of the science part of the PISA+ Study, by inspiring our choices of categories of analysis and prompting the teacher – researcher dialogues.

12.1.2 Commitments: Love and Duty

It has been said that science, at its best, is driven by passion and emotion (Orr 1992). Within the discourse of environmental science Stephen Jay Gould has asserted that "We cannot win this battle to save species and environments without forging an emotional bond between ourselves and nature as well – for we will not fight to save what we do not love". Likewise others have stated: "For the academic worker (here meaning both teacher and researcher), a love of the subject is foremost" (Rowland et al. 1998). However, Lewis Elton (2000) debates the statement. Elton reminds us that; "the word 'to teach' is unique in the English language in that it has two objects – I do not only teach a subject, I do not only teach students; I teach students a subject." (p. 258). Further he claims that good teachers love both their subject and the teaching of it, and that we should not put our passion for a subject above our duty to our students.

Several studies of teacher commitments focus on teachers' unwillingness to change careers and which factors are necessary to increase the quality of teachers' professional work life (Kfir et al. 1997; Louis 1998; Bartlett 2004). In this chapter our focus is the nature of commitments and how these materialize in classroom actions. Becker (1960) explores the concept of commitment and notes that the concept implicitly explains consistent human behaviour. Further he asserts that commitments come into being when a person, by making a side-bet, links extraneous interests with a consistent line of activity. A side-bet is said to be a bond between a prior valuable interest and the new activity. Might a science teacher's love for nature, or love for science be such a side-bet? Another view is that teacher commitment is the psychological identification of the individual teacher with the school and the subject matter or goals, and the intention of that teacher to maintain organizational membership and become involved in the job well beyond personal interest (Graham 1996). It is suggested that commitment is multidimensional and that it should be understood as a mix of commitments to the profession, the school, and the students in order for teachers to have motivation to pursue changes in their practice (Firestone and Pennell 1993; Graham 1996). These concepts of commitment do not conflict with the above assertions about science teaching or with the statements of the teachers' involved in our interviews, and will establish the starting point of the discussion later in the chapter.

12.1.3 A Love Story?

All good love stories in books or movies involve personal contradictions and conflicts in order to develop the story's plot and provide motivation for the characters to act. A person who is content with a situation does not have an inner driving urge to act, and thus there is no exciting story to tell. Inner tensions can therefore lead to altered external actions; the hero or heroine of a love story makes a thrust to win his or her loved one. How does this play out in teaching science? Analyzing science classrooms as an activity system provides us with insight into the dynamics of the classroom. The dynamics are closely related to the contradictions contained in the system, which are considered the subjects' driving force (Engeström 1987; see Fig. 12.1). It is only when an action is connected to doubt, or includes a tension, that the action is dynamic and might be altered; if you are content with an action,

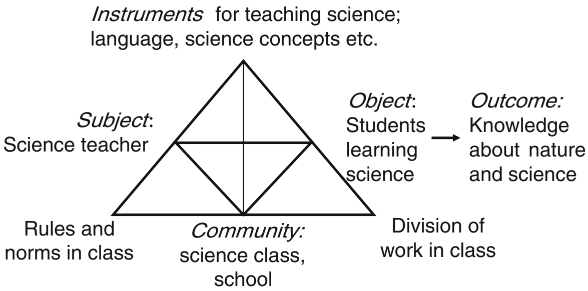

Fig. 12.1 An overview of the structure of the activity of science teaching according to Engeström (1987)

there is no reason to change it. In teaching science, there is an inner contradiction between the use value of the meaning making activities for the individual student, and the exchange value of the students' achievements on tests. ('Exchange value' is the value of achievements in points that can, for instance, be used later to get into schools or universities.) Engeström (1987) describes this as a primary contradiction in the teacher between being a sense-maker and a grade-maker. There might be several other inner conflicts for the teacher connected to their commitment to their profession. Contradictions connected to the teachers' commitment to their students would be described by Engeström (1987) as a secondary level of contradictions, because they are contradictions between the activity system's subject (the teacher) and its object (the student). Contradictions regarding the teachers' commitment to school would also be a secondary contradiction. However, a conflict concerning a science teacher's relationship to science would be a more distant contradiction according to Engeström, because this involves another activity system. Activity systems are networks of human interactions (Russell and Yañez 2003), and a focus on deeper dialectic contradictions might provide us with some insight into how we can change and develop these human interactions. Engeström (1987) argues that individuals often experience these deep dialectical contradictions as double binds, as two demands that cancel each other out. In our case these double binds might be seen as a mix of commitments. Reflecting on and dealing with such contradictions can sometimes lead people to transform their activity.

In the story of love and duty in teaching science we see a complex picture of teacher commitments, and how the different commitments and their contradictions may influence the way science is taught. This chapter will elaborate on the connection between these contradictions, the use of different learning activities, and language as a teaching instrument. Hopefully, looking at science teaching as an activity system may help teachers see their professional work through a different lens and develop their science teaching. The research questions of our study are:

How do science teachers offer meaning making processes to students?
What considerations and commitments motivate teachers in this process?

By analyzing classroom talk (Lemke 1990; Mortimer and Scott 2003), together with classroom activities (Klette et al. 2005), and by using activity theory

(Engeström 1987, 1993), we hope to understand more about how students are offered meaningful learning, and how science emerges as a knowledge culture.

12.2 Methods and Sample

This present part study of PISA+ involves all science lessons from the six PISA+ schools, but interviews of four science teachers are chosen based on the criteria that their science classes had been subjected to practical work in our observation period. All teachers had a substantial science background with either a masters or a major in one of the natural sciences from university or university college.

As described in other chapters, the data were collected by video, observations and interviews. The teachers were interviewed about one selected lesson a week, and given the opportunity to comment on the science lesson videos. The interview was semi-structured and mainly concerned the teachers' reflections about planning and implementing the selected lesson and how typical that lesson was for the teachers' general practice.

Through the systematic use of qualitative and quantitative registrations of teaching and learning activities, tasks, and organizational procedures including aspects of students' autonomy, we have explored subject-specific aspects of science classroom processes (see Table 12.1). We have also studied teacher and student initiatives and language use in the classroom dialogues. We distinguished between scientific and everyday concepts, and analyzed the use of description, explanation and generalization (Mortimer and Scott 2003; see Table 7.1 in Chap. 7). This scientific social language in the science classrooms is an important instrument and cultural tool (Wertsch 2002) for the teacher, and it is used as an indicator of her or his emphasis in science teaching.

Table 12.1 Coding scheme for teaching activities in science lessons (see Arnesen and Ødegaard 2006)

Teaching activities	
Task management	Teacher gives (practical) instructions regarding assignments and class projects
Review	Teacher summarizes in monologue or as students questions about previous lessons' themes
Motivation	Teacher uses an artefact, anecdote or similar to motivate interest in a topic
Teacher summary	Teacher summarizes the theme of the lesson so far
Going over the do now	Teacher asks for results of student seatwork or other work done in the lesson
Going over the homework	Teacher asks for answers to students' homework
Developing new content – canonical knowledge	New knowledge is developed through classroom dialogue, seatwork or in another way
Developing new skills – procedural/experimental knowledge	Practical skills are developed through practical and experimental work

As mentioned, the quantitative analysis of the videos we use the program Videograph.[1] Atlas[2] is used for qualitative analysis of the interviews.

12.3 Results

12.3.1 Teacher Interviews

Utterances from the video initiated interviews where the teachers expressed some kind of dilemma or inner conflict were analyzed in an explorative way in order to find common topics. An example of an utterance of conflict from a teacher interview about how to provide good science teaching, is:

> It's important to find a running red thread. It's not always easy. It depends on how well you know a topic to your finger tips. Mostly the practical part, maybe? At least for me. So if I manage to highlight the red thread, for summing up, and create that contact with the students, then I do believe . . . (From a teacher interview).

These utterances were analyzed in an explorative way, inspired by grounded theory (Strauss and Corbin 1990) to find common topics. This was done by coding the utterances of conflict for content, and after repeated readings, these content codes were again coded for higher level topic codes. The topics were further organized into a concept map in order to find connections and patterns. See Fig. 12.2.

The dilemmas the teacher expressed can be organized in three main groups. The biggest group contains utterances concerned with their own teacher authority or role as a teacher. They show great concern for their students, where caring is the prominent sentiment; "I almost got a feeling of hallelujah when Carl answered, you see, because he hardly ever says anything in class!". The dilemma is how meet the individual needs of their students and at the same time meet the needs of the whole class. During whole class discussions they might realize that individual students are not able to follow. How to address that situation puzzles them. And on the other hand there might be individual students posing interesting questions during whole class discussion. There is always a balance between following up these questions spontaneously and considering whether this is something the whole class will find interesting and useful. As another example of caring, one teacher was concerned with how her humor affected the students. She was a very cheerful person, and often used humor when she expressed herself, but was unsure if the students understood her jokes and irony. She also explained how she deliberately used smiling in difficult situations. "Well, I can talk to them more severely in some situations, if I smile when

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[1] Videograph is a multimedia software package for analyzing video or audio files, e.g. from school lessons. http://www.ipn.uni-kiel.de/aktuell/videograph/htmStart.htm.

[2] http://www.scolari.co.uk/frame.html?http://www.scolari.co.uk/atlasti/atlasti.htm.

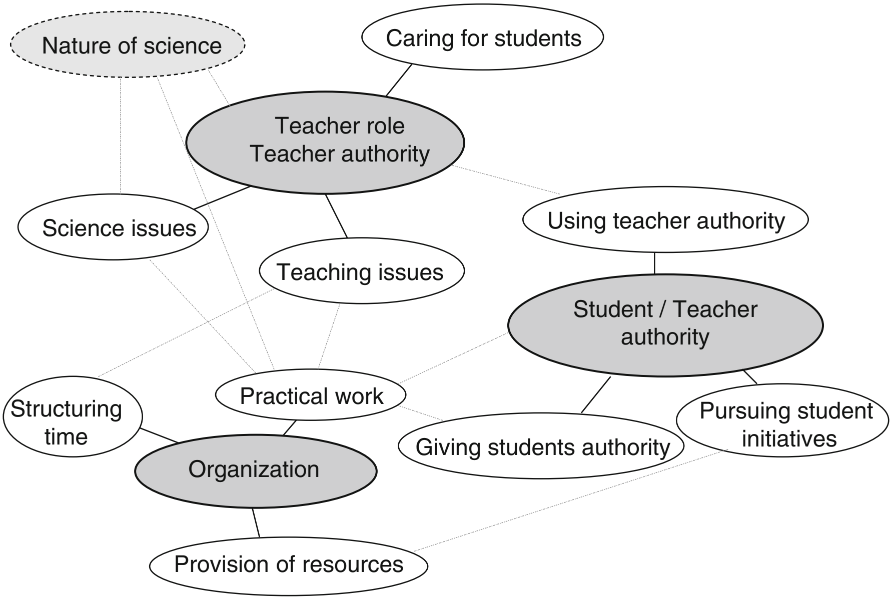

Fig. 12.2 Concept map of the teachers' inner conflicts or dilemmas expressed in the video-initiated interview

I say it." And further she conveys how her cheerful personality can conflict with her role as a teacher and authority; "Because I am usually happy, the students are startled if I raise my voice and fix my gaze. I find that rather comical, and in those situations I have to write on the blackboard. [. . .] I have to turn away in order to get my face together."

Another topic connected to the teacher's role is teaching issues. All teachers are preoccupied with the tension between planning and carrying out a science lesson. "You sit there and plan for yourself, and then, it happens all the time that, no, it doesn't work so well when you are out in class. And even though I have worked for several years, I am not so experienced as a teacher that I can predict what works and what does not." Also the tension between theory and practice is of great concern; whether the students should learn the theoretical background first or start by doing something practical as an introduction to the theory.

Issues connected to teaching the subject science bring up inner conflicts in the teachers. Should they present things as a scientific issue or an everyday problem? Isn't it more important that the students understand a phenomenon than that they know the scientific name for it? Some of the teachers seem confused about being a representative for science and at the same time representing themselves as a person. These issues are also connected to the nature of science (see Fig. 12.2).

The other main group of statements concerns the balance between teacher and student authority. How much should the teacher intervene when students do assignments and practical work? When and how should they give students authority during learning activities, and when should they use their own authority as a science expert or a teaching expert? One teacher stated that she tried to carry out student-centered learning in science lessons. However, watching herself on the video resulted in these reflections: "When I see it now, I think; ohh, so much . . . The teacher talks and talks. But then again, they (the students) have to be inspired, and something has to initiate their thought processes, thus someone has to drive it forward. But the balance . . . "

The teachers express the importance of letting the students be self-contained in their work, but at the same time they feel a need to keep control and to be available for giving help and guidance. "Very often I observe (the students) and think; "What are they doing? Should I go down there? No-o.., it looks like they are doing what they are supposed to." or; "Do I need to stop the situation now? How long have they actually been doing that?" That is the kind of consideration I make."

As shown below, the teachers are very inclusive of student initiatives (Fig. 12.4), and they mediate this in the interviews. At the same time they think continuously; is this worth pursuing? Students' interests and their authority in posing problems are often seen as in conflict with the theme of the day and the teacher's plan for the lesson. The teachers experience this as dilemmas; the choice between pursuing philosophical questions, or teaching scientific facts; following the interest of engaged students or following their own sense of duty in order to get through the science curriculum.

The third main area of concern has to do with organization. It's about how to structure the day and the use of time, for example, the optimum number of science lessons versus converting science lessons to work plan sessions. One example is the trade-off between using time to tell the students what to do, and giving them time to do it. Time and resources for doing practical work are looked upon as a trade-off between economy and pedagogy. Other concerns connected to practical work are the balance between doing and learning, and between letting the students have an enjoyable time and stressing them by requiring a written lab report.

12.3.2 Video Analysis

The videos of the science lessons were coded according to the categories and codes in Table 12.1. The codes allocated to a category are mutually exclusive. The videos were coded by categorizing observable operations on the video on a continuous timeline. The codings were then transferred to a statistics software (SPSS) in order to compare lessons and schools, and the timescale was transformed from seconds to minutes.

In Fig. 12.3 we see the occurrence of each code under the category 'learning activity offered by teacher' across all the observed science lessons. So the scale is actually 6 months which is approximately the observation period. As expected, most of the time in 'our' science lessons was used on developing new content knowledge. We were more surprised by the fact that task management was the next dominating

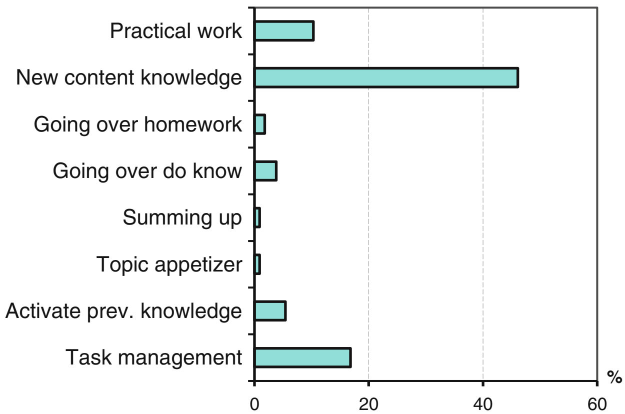

Fig. 12.3 Time used on different activities offered by the teacher as a percentage of filmed time

activity. Much time is used by the teacher telling the students how to solve both written and practical assignments; what and where to write; who to work with and so on. Both these activities are teacher dominated but further analyses show that, in particular, developing content knowledge has a dialogic form, where the teacher includes student initiatives.

Practical work does not feature much in our material (Fig. 12.3). There were some accidental circumstances of this, but it is still a paradox that the teachers spend more time telling the students what to do than offering time for practical work. It is maybe more disturbing that teachers seem very rarely to sum up lessons, go through work done during the lesson and homework. To explore this result we looked more closely at the seatwork done in lessons. Traditional seatwork such as answering written questions was gone through, but for the most part the seatwork was project work, workplan assignments and writing lab reports. Because of the nature of these learning activities the teachers' evaluation of this work is given later. Project work and workplan assignments are relatively new learning activities designed to deliver individually adapted education which is emphasized in more recent school policy. The activities do seem to result in more individualized learning.

In our analysis, the classroom dialogue is coded during whole class instruction, not when the teacher is giving individual guidance. We distinguish between when the teacher is talking in a monologic way (teacher exposition), when she or he asks the students questions (teacher initiative), or when the students take the initiative to ask questions or make comments (see Table 7.1 in Chap. 7). We see that in the classrooms we observed, although the teachers speak or take the initiative most of time, they often include student voices, and the dialogue is not infrequently directed by student initiatives (see Fig. 7.2 in Chap. 7). Even though teachers are attentive to student voices, they made little use of peer discussions as a meaning making activity.

We have focused on three different features of scientific social language: description of a phenomenon or system; explanation of a phenomenon or system, and generalization, which involves a description or explanation without specific context. Although coding was done both during whole class instruction and while following the teacher during individual guidance, only a small part of the time was the focus on any of these three features. The totally dominant feature was description, even during one-to-one talks between teacher and student (see Fig. 7.1 in Chap. 7). This gives us an idea of how science is portrayed for the students and what type of knowledge is emphasized.

The category called social language tries to capture whether the social language used in classroom talk was of an everyday or scientific nature. It turned out that it was difficult to achieve sufficient reliability when coding this category. However, overall we can say that everyday language was significantly dominant (see Fig. 2.4 in Chap. 2).

12.4 Discussion

In this section we would like to shed light on how teacher commitments, which are embedded partly in the teaching science activity system and partly in the teachers' personal interests and preferences, may influence the teachers' actions in the science classroom. These actions will further influence and constitute part of the larger-scale and longer-term activity system of teaching science, which to a certain extent is illustrated in our summaries of the video analyses.

The teacher interviews revealed three main areas of concern, based on the dilemmas or inner conflicts expressed by the informants. The most common focused on the teacher's role and teacher authority. Another area centered on the tension between student and teacher authority. The third area of concern was organizational issues. These three areas seem to link to the commitments outlined by Firestone and Pennell (1993). Teacher's role and teacher authority are issues connected to commitments to the teaching profession. Tensions between student and teacher authority are mostly connected to the teachers' commitment to the students. And finally inner conflicts concerning organizational issues are mainly related to the teachers' commitments to school. However, you will find more or less a mix of all these commitments in all three groups.

Teacher commitments towards school contain both commitments to their own school and to school as an institution including the national curriculum. In the curriculum there is an emphasis on individually adapted education. Several schools have met this demand by introducing work plans, or project work. In addition the science curriculum encourages the use of practical activities. The teacher interviews illuminate teachers' thoughts around these issues. Looking at the results from the video analyses (Fig. 12.3), we see that much time is spent on task management. On the other hand, learning activities such as summing up, going over the do now and going over homework are seldom offered by the teachers. As shown previously, this is because seatwork assignments are often work plan tasks, project work and writing lab reports, which all require postponed evaluation. So teachers' commitments to school may result in actions that result in science teaching lacking any continuous evaluation of seatwork.

Teachers' commitment to their profession involves offering good meaning making situations to the students learning science. In order to do this the teacher has to consider both the science subject and the learner. This topic is frequently mentioned by the teachers, which indicates its importance. The topic includes both planning and revising learning activities, theoretical and practical perspectives on science, and defining oneself as a person teaching science. We see in Fig. 12.3 that developing new content knowledge is the most distinctive learning activity. The teachers express empathy with their students and care especially about the weak performers. One of this study's surprising results is the strong emphasis among the teachers on the language feature of description. Could this possibly be connected to the traditional image of the teaching profession, whereby the teacher tells the students about canonical science facts? The teachers might also perceive that descriptions are easier for all students to understand.

In our study the teachers' commitment to their students seems to be very strong. It permeates all the interviews, and includes caring for both individual students, the class as a whole and their meaning making processes. Video analyses show us how this results in science lessons that are inclusive of student views (see Fig. 7.2 in Chap. 7). The teachers express a dilemma between letting the students work autonomously and intervening to keep control. They may appear to lack confidence about when it is legitimate to intervene and use their teacher authority, and when it is appropriate to give the students authority. In our study we found that the distinction between scientific and everyday language was not easy to make, but everyday language was the most dominant. Knain (2005) shows how expressive writing in science focuses on the individual's need to reflect and understand and thus uses more everyday language. Transactional writing (like lab reports) is more formal and directed towards others in order to communicate and inform, and contains more scientific language. It is highly likely this also applies to the orally spoken language in science lessons. Could it be that the teachers' dominant use of everyday language at the expense of scientific language is linked to their desire to meet the individual student's aspiration for understanding? An undesirable consequence of this would be that the students encounter less scientific language in their lessons.

This classroom video study provides rich and interesting data on how science teachers act and think during science lessons. The teachers in our study convey the impression of high accountability for their work. They express commitment to meeting each individual's educational needs, a goal that is heavily emphasized in the Norwegian curriculum. At the same time they express frustration over not being able to meet so many different requirements, which is connected to commitments to their profession. They also articulate commitment towards their school and its organizational structure.

In the story of love and duty in teaching science we see a complex picture of teacher commitments (Fig. 12.4), and how the different commitments and their contradictions may influence the way science is taught. The teachers' commitment to school is expressed as a strong feeling of duty, and is of course primarily based

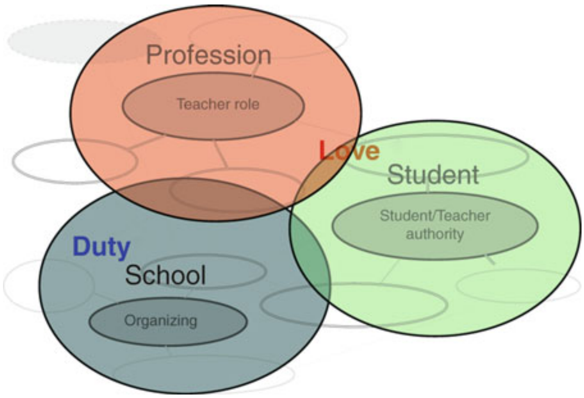

Fig. 12.4 Connections between teachers' conveyed expressions of tensions and dilemmas and their expressed engagement

on their working contract. On the other hand their commitments to the students and their profession are more characterized by love. This might be because they attach valuable interests to this line of activity.

Hopefully, telling this 'love story' will illuminate some of the complexity in a science teacher's day and help them to see possibilities for alternative actions in order to obtain what they would consider a happy ending.

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