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

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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

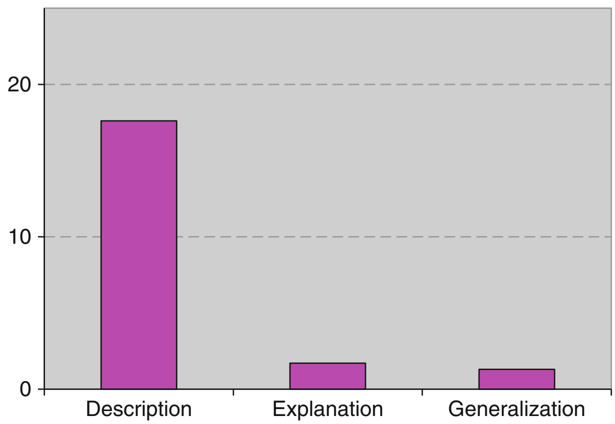

Fig. 7.1 Use of scientific features following the teacher during the whole lesson as a percentage of videotaped science lessons

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

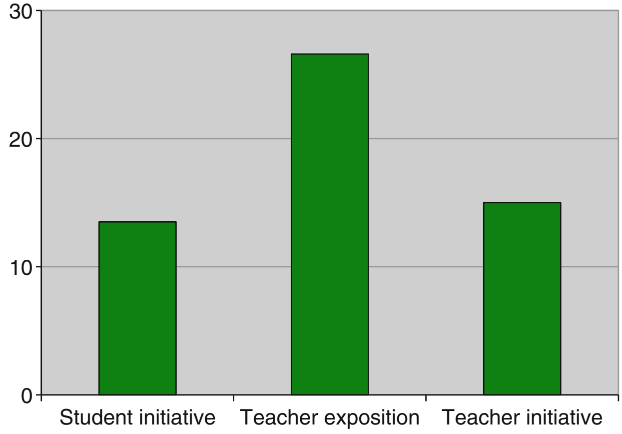

Fig. 7.2 Classroom dialogue during teacher led instruction as a percentage of videotaped science lessons

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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