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

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Abstract In this paper the role of explanations is discussed in relation to possible consequences originating in the polysemy of the word explanation. The present study is a response to conceptual confusions that have arisen in the intersection between theory and practice, and between science education literature and communication in authentic science classroom settings. Science classroom communication is examined in terms of one teacher's word use during eleven lessons about evolution. The study contributes empirical examples of how disciplinary norms of valid explanations are manifested in science classroom communication. A dialogical analysis shows how the teacher provides three conversational structures: asking for acts of explanation, providing opportunities to talk about what explanations are in this context and providing opportunities to talk about explanations constructed by students. These three structures facilitate the process of learning how to evaluate and justify explanations. Three potential meanings of the word "explanation" are pointed to: an everyday meaning, a pedagogical–professional meaning and a scientific meaning of the word. It is suggested that the co-existence of these three potential meanings has communicative consequences in science education.

Keywords Explanation · Classroom discourse · Dialogism · Video analysis · Evolution · Science education

Bruket av"förklaring" i naturvetenskaplig undervisning: en fallstudie

Studien tar sin utgångspunkt i litteraturen och en aktuell diskussion angående förklaringar. *Vad är en förklaring?* och *Vad innebär det att förklara?* är frågor som har en lång historia och som ger möjligheter till flera olika svar och skiftande betydelser av ordet *förklaring*. Frågan

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som ställs i denna studie är hur en lärares undervisningspraktik påverkas av att ordet används på många olika sätt. I detta sammanhang relateras till tre olika meningsbetydelser av förklaringar: *en vardaglig, en pedagogisk-professionell* och *en naturvetenskaplig*.

Den empiriska basen är en fallstudie av hur en lärare använder ord som ”*förklara*” och ”*förklaring*” i samtal med elever under en serie lektioner om evolution. Ett dialogiskt perspektiv används för att analysera den kommunikation som sker mellan läraren och eleverna i klassrummet. Resultaten visar att under de 11 lektionerna använder läraren ord som”förklara” och ”förklaring” vid 98 olika tillfällen i olika meningskonstruktioner och sammanhang. Det görs för att uppmuntra och utmana eleverna att göra uppgifter och för att hjälpa eleverna att utveckla kunskaper om hur olika typer av förklaringar kan utvärderas och bedömas. I genomförandet av olika klassrumsaktiviteter iscensätter läraren tre olika samtalsstrukturer där förklaringar förekommer. Det är när läraren efterfrågar en förklaring, när läraren tillsammans med eleverna samtalar om vad en förklaring är i denna undervisningskontext, och när läraren tillsammans med eleverna samtalar om elevernas sätt att förklara.

Studien visar att flera olika meningsbetydelser av ordet förklaring samexisterar i kommunikationen i klassrummet. Vid ett tillfälle diskuterar läraren tre olika historiska modeller för att förklara den biologiska evolutionen, den bibliska skapelseberättelsen samt de två olika evolutionsteorier som Lamarck och Darwin formulerade. I detta samtal behandlas den bibliska skapelseberättelsen både som en typ av förklaring, samtidigt som läraren genom att använda gester och peka på grundantaganden tydligt visar att det är en förklaring som inte är relevant i sammanhanget. Vid ett annat tillfälle uppstår ett samtal om hur eleverna i sina försök att förklara giraffens evolution blandar inslag från Lamarck och Darwin. Samtalet behandlar ordet förklaring omväxlande i en vardaglig mening: som något som bidrar till en ökad orsaksförståelse om varför livet har utvecklats, och i en pedagogisk-professionell mening: som en kausalt uppbyggd händelsebeskrivning av hur livet har utvecklats.

Med utgångspunkt i det dialogiska perspektivet kan de 11 lektionerna i sin helhet ses som den förklaring till evolutionen som eleverna erbjuds genom undervisningen. I den förklaringen kopplas den vetenskapshistoriska utvecklingen av olika teorier om evolution samman med undervisningsinnehåll som reproduktion, genetik och biologisk variation. Beskrivningen av de tre meningsbetydelserna av *förklaring* och deras samexistens i det naturvetenskapliga klassrummet möjliggör ett tydligare bruk av ordet både i litteratur och klassrumsverksamhet och kan därmed bidra till en fördjupad förståelse.

The words *explanation* and *explain* are used to convey several different meanings in science education. As a metalinguistic term, *explanation* refers to the constructive process of explaining and to the semiotic artefacts that are produced (Wells 1999). The word *explain* shares the functions of being a speech act in conversation (Searle 1971). As a science teacher’s speech act, the use of the word *explain* has the power to initiate student responses in more than one way. The question in this paper is what consequences the potential meanings of the words *explanation* and *explain* have for science teaching practices. The current paper is focused on the investigation of word meaning and uses a framework that views science teaching as being primarily a communicative activity.

The word “explanation” in literature

Explanation is a word that has been widely treated in philosophy, used as a resource in science and is central to the field of science education research. Herbert Horwood (1988) formulated two sets of questions regarding explanations in science education because of

the way he considered *describing* and *explaining* to be indicative of the state of science teaching. The first questions are: "How do teachers use the terms? And what might students learn from this about the nature of the activities we know as description and explanation?" (1988, p. 43). The second set of questions address what the role of explanation in science teaching ought to be:

> …how are we to construe the role of the science teacher in communicating the explanatory models developed and adhered to by scientists? Should teachers' explanations to pupils be fully congruent with the accepted research explanation? Is the proper explanatory role for a science teacher to promote learning of the current scientific explanations? The related question is to ask how a person goes about learning how to explain things when there is no teacher to do it? Is it possible that science teachers have a role to play in helping pupils develop explanatory ability—this latter as distinct from being able to recite the explanations of others? (Horwood 1988, p. 43)

In this quote, Horwood separates the pedagogical activity of *explaining something to somebody* from the research activity of *explaining something*. In this way he problematizes the role of the science teacher and its communicative challenge. Horwood also uses examples from tests and text books to illustrate *description* and *explanation* generally and *dormitive explanations* specifically. A dormitive explanation refers to an appealing but less vigorous explanation that, according to Horwood, in its simplification may inhibit future learning.

Lay Hoon Seah, David Clarke and Christina Hart (2011) distinguished two uses of *explanation* in their detailed study of one science teacher's talk in the context of a unit about expansion and the particle theory of matter. The diverse pedagogical uses of the word ranged from definitions of terms to descriptions such as clarifying details in a procedure, while the scientific uses involved accounting for scientific theories or concepts. The authors conclude: "The teacher's use of the word explain with multiple meanings might have framed different interpretations and assumptions among the students about what it meant to explain in the context of a science task" (2011, p. 866). When students relate only to a macro-level in their answer to a task, Seah and colleagues suggest that this was a consequence of interpreting a sufficient explanation to mean giving a description of what happened. When students interpreted the word in the scientific sense, according to these authors, this would be more likely to involve giving accounts of expansion in terms of the relevant scientific theory, in this case the particle theory of matter: "Thus, in completing the two tasks, one challenge for the students might have involved understanding what kinds of response would qualify as an explanation" (2011, p. 866).

Traditionally the science education research field presumes that the functions and uses of explanations are intimately connected to the understanding of a focused scientific topic. The approach of categorising answers to why and how questions and understanding them as alternative explanations or preconceptions in relation to the scientific explanation of a phenomenon is still employed (Vosniadou 2012). This has been called a disciplinary approach because of the way analytical generalizations are oriented towards scientific principles (Kelly, McDonald, and Wickman 2012). This research tradition seeks to improve the teaching of particular topics and understand students' learning of these topics. According to David Geelan (2012), research that deals with teachers' explanations has focused on the nature of the kinds of explanations used or has described (and prescribed) what an explanation of high quality might mean. Research about students' epistemic

insights (Billingsley, Taber, Riga, and Newdick 2013) and children's teleological explanations (Kampourakis, Pavlidi, Papadopoulou and Palaiokrassa 2012) have investigated scientific explanation in relation to religion and beliefs.

One line of research discusses explanations in terms of opportunities to engage in scientific argumentation. Part VII of Fraser et al.'s International Handbook of Science Education (Fraser, Tobin, and McRobbie 2012) takes the extensive literature on students' argumentation into account. For example, Maria Pilar Jiménez-Aleixandre and Bianca Puig (2012) develop research on how to stimulate students' critical thinking, particularly their evaluation of scientific evidence. However, in the investigation made by Victor Sampson and Margret Blanchard (2012) of how teachers create arguments, few teachers included evidence as support for an explanation. Another example is Leema Berland and Brian Reiser (2009) that examine how students construct and defend explanations. In this context they emphasise the three goals of sensemaking, articulating and persuading.

Signs of conceptual confusion

The many roles of *explanation* in science education are debated and explicitly problematized by Jonathan Osborne and Alexis Patterson (2011) with a response by Berland and Katherine McNeill (2012) and with further contributions by Melissa Braaten and Mark Windschitl (2011). The debate contributes to theoretical descriptions of valued and desired meanings of *explanation* in science education. Osborne and Patterson (2011) question current conceptualisations of the word *explanation* in science education and identify a growing confusion between uses of the word *argument* and the word *explanation* in literature. The authors express worries about this confusion and perceive a weakness in the field:

> We wish to argue, moreover, that the failure to distinguish between these two concepts is a weakness in the field. For, if a field lacks clarity about the concept that it seeks to explore and promote as a feature of classroom practice, then it will fail to communicate its meaning and intent to the wider audience of curriculum developers, standards developers, and teachers. (Osborne and Patterson 2011, p. 628)

The weakness is presented in terms of its consequences for the legitimisation of the research field. In order to take responsibility, the authors define *explanations* and *arguments* as being two separate discursive acts. While scientific explanations attempt to answer three questions: *what we know*, *why it happens* and *how we know*, school science explanations focus on the causal *why*-question. The text takes its point of departure in the causal explanations used in schools by elaborating on the relation between the phenomenon (the *explanandum),* and its explanation (the *explanans*) meaning how this phenomenon came about. The quality of an explanation is presented as being connected to whether it generates increased understanding. For science teaching this implies that one measure of its quality might be "…the extent to which it achieves this sense of increased understanding" (Osborne et al. 2011, p. 629). According to the authors one particular characteristic of explanations is that the phenomenon, the explanandum, is presumed to be true. Differences between teachers providing explanations and students constructing explanations are also pointed out. The authors claim that the explanatory hypothesis represents a discursive overlap dependent on a process of argumentation and successively being recognised as an explanation.

Two educational strategies addressing the problem of the overlapping use of argumentation and explanation are explored by Berland and McNeill (2012). Berland and

McNeill see argumentation and explanation as complementary scientific practices whose synergistic relationship, apparent in discussions, also shapes students' written explanatory products. The authors worry about the implications of the strategy suggested by Osborne and Patterson. If the strategy of emphasising distinctions between *argument* and *explanation* influences teachers, this might lead to the adaptation of less meaningful classroom activities. Previous studies by these authors represent a second and alternative approach: *argumentation* as designation for what happens when the goals of scientific explanation and argumentation are encompassed by sensemaking and use of persuasion by teachers and students in the classroom.

Braaten and Windschitl (2011) present five models of scientific explanations from the philosophy of science. Their parallels in the science classroom are: the "covering law" model, the statistical–probabilistic model, the causal model, the pragmatic model and the unification model. These authors claim that conceptual clarity can help "…science educators envision what 'counts' as a big idea in science lessons…" (Braaten and Windschitl 2011, p. 650). To use frameworks derived from the philosophy of science is suggested as one way to attain clarity. Here, five distinct uses of explanation in the field of science education are presented. In line with the explanatory hypothesis by Osborne and Patterson, Braaten and Windschitl suggest *explication as justification,* as well as other uses of explanation like *explication* and *simple causation*. Attributes of *explanation as explication* are when the teacher requests definitions of terminology or teachers or students request metacognition about reasoning and problem-solving strategies. Additionally, in response to influential curricula and policy documents from the USA, UK and EU, a conceptual and pedagogical tool for scientific explanations in the classroom is created. The explanation tool seeks to help teachers envision and evaluate the depth of students' explanations.

A scaffolding framework on how to frame content dialogically as part of *explanation* and *argumentation* is presented by Michael Ford and Brian Wargo (2012). They find dialogical perspectives helpful in identifying desirable classroom activities and vectors for learning. Two activities during one lesson in a 9-week unit about evolution are analysed. The classroom represents a discursively monologic and ideologically dialogic context. The analytical framework consists of examples and designations of teachers' discursive operations while lecturing on five levels: *nonact*, *recount*, *explain*, *juxtapose* and *evaluate*. Understanding an idea in science is considered by Ford and Wargo to be both conceptual and epistemic. When students are considering a multiplicity of ideas they can improve their thinking *with* the idea being learned. The authors have two claims: students discussing ideas with each other ought to be a preferred classroom activity, moreover: the outcome of education ought to be understanding itself. A student's understanding of an idea in science could be demonstrated by an ability to use it in activities such as explanation and argumentation and would include: (1) being able to use the idea to explain natural phenomena (2) being aware that it is one among a multiplicity of alternatives and (3) that the scientific idea is superior to alternatives because scientific evaluation takes evidence into account.

Three potential meanings

In summary, the word *explanation* has several meanings for teachers, students and science educators. First of all, the two words *understanding* and *explanation* have an intricate relationship. The philosophical and historical constituents of this relationship were developed at length by George Henrik von Wright (1971). One aspect of this relation is reflexive. When a student says: "*I have an explanation",* this possibly implies that the

student claims or expresses the experience of understanding something. The *sense of understanding* has been discussed as what mainly guides evaluations of explanations as being good or correct (Trout 2002). Second, when someone claims to be able to explain something, this might mean that the person believes themselves to be able to formulate a causal relation between events, according to the local norms of form and content. Third, in another situation the same expression might involve epistemological claims based on empirical and logical conditions. Therefore, when teachers and students recognize something as an explanation, there are several possibilities for what the intended meaning is. The above brief description can be synthesised into three potential meanings of the word *explanation*:

1. Explanation in the everyday sense of the word. The use and meaning of the word *explanation* serves the various purposes of someone seeking to understand and learn about something. Here, the word explanation designates answers of different kinds including recounting of events, anecdotes and the formulation of life histories. This use and meaning can also involve efforts to help other people to understand.
2. Explanation in the pedagogical–professional meaning of the word. This relates to educational purposes of making evaluations of formulation in talk or written language in relation to subject-specific norms. In an educational context, a teacher may ask a student to contribute an explanation that can be made the subject of an evaluation.
3. The scientific meaning of the word explanation. This meaning of the word establishes causal and conditional relations between sequential events. In this sense explanations might be used to determine outcomes. The scientific argument comprises the rationale behind and the interrelations between explanation and evidence.

Listed are three potential meanings of the word explanation relevant to a science teaching and learning context. The list works for theoretical reasons. For example it illuminates the fact that different uses of the word explanation involve different evaluative perspectives. Scientific explanations are evaluated according to their predictive value and evaluations of explanations in education are based on subject-specific norms defined in curricula. In everyday use, the evaluation of whether an explanation makes sense is a process of negotiation internal to the individual or between individuals. One consequence of this is that the separate meanings create opportunities to make epistemological claims of varying strength.

It can be assumed that the listed meanings co-exist, overlap and combine in spoken interaction. For example, in science classroom communication the teacher and students use the word for different purposes, which evoke different meanings of the word. When the teacher uses the word *explanation*, this implies a pedagogical–professional meaning of the word that involves an evaluation of students' use of language in relation to the disciplinary norms of the specific curricular topic. When a student uses the word *explanation* in the processes of meaning making, this implies an everyday meaning of the word. When teachers and students talk about explanations in the classroom, teachers' evaluative processes and students' meaning-making processes are potentially in conflict.

What is particular to science education (as well as science classroom communication) is the parallel use of the scientific meaning of the word explanation. The scientific meaning of the word introduces additional complexity to the communication.

In order to contribute empirically, this study re-examines the use of words such as *explanation* and *explain* by teachers and students in science-teaching practice. Such an endeavour seeks to discover the meaning of these words as they were used in teachers' and students' participation in activities. This does not exclude curricular regulations, subject-

specific goals or disciplinary norms but regards them as interwoven into the structure of activities in the practice. The first set of questions by Horwood (1988) guides the study design: How do teachers use the terms? And what might students learn from this about the nature of the activities we know as explanation?

A dialogical perspective on science teaching

This study takes a dialogical perspective on science teaching as a communicative activity. This means that a monological perspective on perfect communication as transfer of information is rejected. In the writings of Mikhail Bakhtin (1981) a dialogical perspective on communication was founded and has later been developed and successfully applied to educational research. The following theoretical review contributes as a background to decisions made in the study design and conducted video analysis.

Dialogism as paradigm and framework

Per Linell (2009a, 2012) writes about dialogism as a paradigm embracing theories on sociality, interaction and communication primarily dealing with the human mind. Dialogicality refers to how human beings generally make sense of the world in meaning-making activities mediated in and through language. Linell (2009a) describes four fundamental assumptions underlying dialogical theories of communication. The first assumption of communication as sufficient understandings for current, practical purposes opposes models of perfect communication and complete understandings. Instead a sustained communication indicates sufficient understandings for participants to proceed with whatever they are doing. A second assumption has to do with co-authorship and implies that interpretations of utterances are negotiated in dialogue between speaker and interlocutors. Third, the theory of meaning potentials (Linell 2009a, b) says that words do not have one lexical meaning; instead they carry potentials for meaning. Fourth, cognition and communication are interdependent since the formulation of any cognised content will at the same time transform the content.

Three dialogical principles

The ways single utterances build connections and make participants responsible have been called the three reflexive principles of dialogism: sequentiality, joint construction and act-activity interdependence (Linell 2009a). The three principles constitute a kind of "constrained holism" for talk-in-interaction. The act-activity interdependence points to how each individual performed act is dependent on the activity as a larger communicative undertaking, while the activity is realised in and constituted by the individual acts. For interactions in school, the social circumstances include the institutional characters of this practice, for example extensive educational goals. At the same time individual acts, utterances and doings constitute the classroom activity and it is only through these acts that the classroom activity becomes realised.

In Eduardo Mortimer's (2010) conceptualisation of Bakhtin's dialogism, the three principles are recognised as contextual aspects of utterances:

> This contextual aspect is, therefore, the expression of the concrete, historical situation that engendered the utterance. Three different but related aspects constitutes the context: the spatial horizon that is shared by the speakers; the knowledge and comprehension of the situation by the speakers; and the common evaluation they have of the situation. It is by this three-dimensional model that someone is able to understand what is presumed in an utterance, what remains not said. (Bakhtin 1935/1981) (Mortimer 2010, p. 151)

This description of the contextual aspect emphasises communicative understanding. Here, communicative understanding is the reciprocal relation between speaker and listener and between what is actually said and what speaker and listener presume to be said. Drawing on Vygotsky, Wolff-Michael Roth (2010) claims that the analysis of word meaning requires a cultural-historical analysis of the situation as a whole. This view considers the essence of word meaning to be located at the intersection of private thought and public language and one form of consciousness: knowing together. Pei-Ling Hsu (2010) expands on the analysis of one professor interacting with a graphical representation during lecturing. Hsu finds that the orientations of the professor, the use of words, gaze, gaze trajectories, gestures, body movements and spatial distance from the chalk-board indicate interactions with a second audience: the inscription itself. Based on this re-analysis Hsu discusses the dialogical relationships that constitute speech: the ones between speaker and audience, speaker and language, thought and language.

The three dialogical principles, as described by Linell (2009a): joint construction, sequentiality and act-activity interdependence, allow the analyst to make methodological applications. In classrooms, the interaction between teacher and students is organised in certain ways, which can be seen as one result of the principle of act-activity. For individual utterances, sequentiality is displayed in their responsive and projective properties. The responsive property connects the utterance to what was immediately preceding in the conversation. The projective property of an utterance stipulates expectations about ways for an interlocutor to respond. Projective and responsive properties of an utterance charge what is said with meaning in relation to one or more communicative projects in the communicative situation. The principle of joint construction is derived from the assumption of co-authorship and negotiation of meaning. This principle works to establish one utterance in the context of communication between participants and their processes of co-construction of meaning. For a sustained communication, speaker and listener need to share some background knowledge or share contracts regarding how things are to be understood (Hanks 1996). For single words this matter might be discussed using the theory of meaning potentials (Linell 2009a, b). Meaning potentials are derived from traditions of language use and therefore abstract by nature.

Designing an investigation of word meaning

The dynamic view of dialogisms affords opportunities to make investigations into the details of how the meanings of the words "*explain*" and "*explanation*" are negotiated, understood and made manifest in science classroom communication. The theoretical assumptions provide a foundation for the methodological decisions in design and subsequent analysis.

Generating the data

The material for the study was provided by the project Science Literacy in Classrooms, a collaborative project, which was facilitated by the technical assistance of a video-lab.

The data was collected during the spring semester 2011 with the use of a technological design that was provided by an original methodology developed in an Australian study (see Clarke et al. 2012). Four cameras and wireless microphones were used to capture the complete teaching of one science unit. One camera was trained on spotted the teacher, one an overview of the classroom and two cameras focused on the work of two groups of students. In this way, the teacher's talk and interactions were covered together with an over-view of the interactions in the classroom and close-ups on groups of students for the complete science unit. The recorded material consists of 11 lessons each lasting for 50 min.

The case for investigation

One teacher volunteered and the students in her class agreed to participate in the study and the capturing of a complete curricular unit about biological evolution. The unit consisted of 11 lessons over the course of 4 weeks and a summative test a couple of weeks later. The students were 15 years old and the study was performed during their final semester in lower secondary school, grade 9. This teacher had been responsible for the teaching of science subjects in the group for 2 years and the group was well known to her. She described them as having average skills and as a group of students that actively contributed to classroom conversations. The school was situated within commuting distance of a large town in Sweden and had about 300 students. The teacher was formally qualified and had about 10 years of experience as a teacher. The seating in the classroom was organised according to the requirements for the technical setup (i.e. tables for groups of students). Apart from this, the research team did not intervene in the planning of the series of lessons. The teacher was asked to teach the unit about evolution the way she usually did.

The teaching was dominated by whole-class teaching in combination with organised small-group discussions and task work. During the small-group work, the teacher participated by interacting with groups of students. In the first lesson the students were introduced to a task where they were asked to explain the evolution of the giraffe's long neck. In the second lesson the teacher introduced three theories from the history of science about the evolution of life on earth. In the communication during the rest of the sequence, the teacher and students repeatedly returned to aspects of what was discussed and written down during these first two lessons.

Previous approaches to word meaning

The video-analytic method is influenced by methodological approaches in previous studies of word meaning and word use. The study by Oskar Lindwall and Gustaf Lymer (2011) is interesting because of the pragmatic approach used to distinguish aspects of pragmatic relevance to participants in a practice. The study shows how particular word use informs participants about interactional patterns. Selected expressions such as "*I don't understand*" and "*Do you get it?*" prove to be important for the closing and opening of task-based activities. There are similarities between the linguistic expressions in focus in the present study and those in focus in the study by Lindwall and Lymer. In the analysis provided in

this paper the pragmatic approach is adapted in terms of striving for analytical demarcation of what expressions like *explanation* appear to imply in a science classroom context.

Video technology allows detailed studies of classroom interactions and has the capacity to capture large bodies of materials. Methods of building collections of particular words in context from large corpuses is described by Neil Mercer (2002). Mercer refers to this organisation of data as a concordance:

> It [a concordance] can reveal that certain words or phrases recur in a way that seems important for the developing meaning of what is being said as the conversation unfolds. This enables an analyst to form a kind of hypothesis about how the speakers are developing themes in their shared understanding. (Mercer 2002, p. 68)

The procedure is found to be one way to reveal meanings that are not captured by literal and formal definitions, and a similar procedure is therefore applied in this study. Here, the many roles of *explanation* in science education are explored in a case study of one teacher's explicit use of the words "*explain*" and "*explanation*".

The making of a collection

For the purpose of the study, 9.5 h of video from the teacher camera and verbatim transcripts constituted the primary data, which was complemented by video and transcriptions from three additional cameras from the same classroom: in total 38 h of video. The availability of the three supplementary cameras was useful when contextual aspects of the teacher's interactions needed clarification. The large body of material initiated an analytical process that proceeded in three steps: (1) Construction of a collection of word use in context, (2) Analysis of patterns in word use and (3) Analysis of word meanings.

For the collection process instances in the transcribed talk including words associated with the words *explanation* and *explain* were selected. The words included corresponded to Swedish translations of the English words: *explanation, explanations, the explanation, the explanations, explain, explained, has/have explained, explaining*. The collection was assembled as an archive together with information on the sequential occurrences of each instance in the complete data material.

After the collection had been put together the second step involved analysis of grammatical patterns in word use and responsive and projective properties of utterances. The use of the selected words in the context of directives or assertives was investigated. The analysis used the three dialogical principles: sequentiality, joint construction and act-activity interdependence, to find relations between the teacher's individual utterances and the teaching as a whole sequence of lessons.

In the third step the video recordings were revisited and analysed. This involved focusing on particular instances and making revised, more detailed transcriptions of particular episodes based on transcript conventions (see "Appendix"). The more detailed transcriptions were successively developed into the analytical descriptions and short excerpts, and were included in the findings. The dialogical perspective contributed to understanding the flows of interaction as nested communicative projects (Linell 2009a). This facilitated finding interactional structures in communication like the IRE/IRF structures as described by Jay Lemke (1990), Mortimer and Phil Scott (2003) and by Gordon Wells and Rebeca Arauz (2006), episodes addressing particular topics and phases in the performed activities, all of which were the result of communicative projects of varying size that were being conducted. In the third step word meanings in their communicative context and the details of interaction were distinguished.

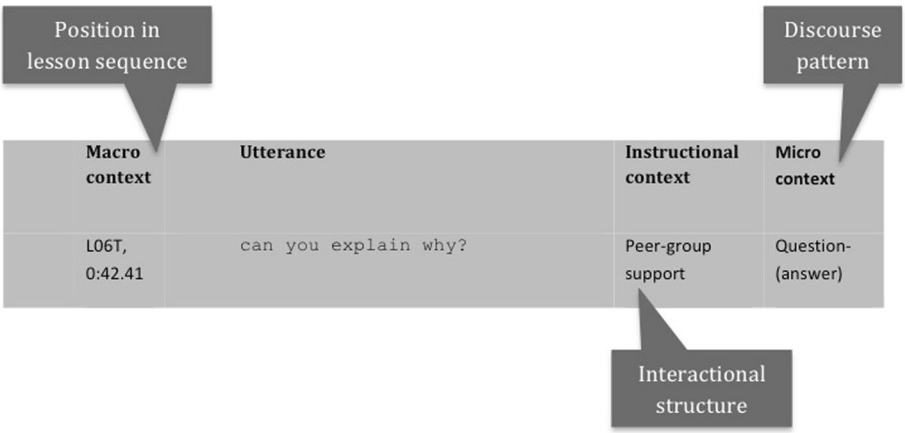

Fig. 1 Data representation

Data representations

In the Findings section, data is represented in two formats: tables and detailed excerpts. The tables show the various uses of the words in the different contexts over the course of the teaching sequence. This corresponds to the second level in the analytical process: patterns in word use. Figure 1 displays one expression from the material in the table format.

In the left column, the position of the particular utterance in relation to the lesson sequence as a whole is noted. This information is used in order to relate the talk to the overview of the sequence (see "Appendix"). The numbers L06T indicates lesson number 6 and teacher camera view. The numbers 0:42.41 indicate the amount of time elapsed in this particular video recording, in general the position of this utterance relative to the start of the lesson. The two columns to the right include information about the interactional context of the particular utterance. The first column to the right gives some information about the classroom activity that is going on, whether the teacher is lecturing, supervising or giving a group of students' instructional support. The second column to the right gives information about the conversational structure in terms of speech acts (Searle 1971). Information about the particular assignment or current writing on the whiteboard is included above the table when appropriate.

Three detailed excerpts of the interaction between the teacher and students are included with analytical descriptions. These excerpts include information about the macro context of episodes: lesson number, camera view and time-span. For transcript conventions see "Appendix". The three dialogical analyses provided with the excerpts correspond to the third level in the analytical process: word meaning.

The findings of three conversational structures

This section shows the co-existence of different meanings of the words *explain* and *explanation* as manifested in science classroom practice. Structurally the section consists of three parts preceded by an orientation to the various forms of the words found over the

Table 1 Instances of [förkl*] or [expla*], in teacher talk

	Case study
Recorded lessons (50 min)	11
Lessons in the sequence	11
Instances in sequence	98

course of the 11 lessons. In the three following parts examples of word use in context and longer excerpts are provided that show how the teacher approached explanation construction and provided ideas about explanations.

The teaching included activities such as the students writing short texts and discussing the texts, practical activities, discussions of textbook problems and lecturing (see "Appendix" for an overview). Transcripts from recorded talk enabled the construction of a sample, Table 1.

Instances in the teacher's talk which included the verb *explain* [förklara], the noun *explanation* [förklaring] and variants were focused on. This resulted in 98 instances, in translation (Swedish word, number of instances): *explain* (förklara, 38), *explanations* (förklaringar, 27), *explanation* (förklaring, 21), *the explanation* (förklaringen, 4), *the explanations* (förklaringarna, 3), *explained* (förklarad-e, 2), *has/have explained* (har förklarat, 2), is *explaining* (förklarar, 1), see Figs. 2 and 3.

The teacher used the target words in the instructional context of lecturing, task instruction and peer-group support. For example "*explanation"* was used in reference to students' text products, regarding certain events and models in the history of science, and the teacher's own communicative undertaking. "*Explain"* was used to encourage students to work, make a request for an answer and in making assessments. The language use and frequency of the targeted words were consequences of the interplay of the particular classroom context and the organised activities that the participants engaged in. During the first lesson, one task was given with the explicit request directed for the students to explain and provide written explanations. This was reflected in the frequent use of the word *explain* during Lesson 1. In Lessons 2, 3 and 4, historical explanations for the development of life on earth were introduced and compared with students' constructed explanations of the development of visible traits of particular animals (giraffes). These activities were reflected

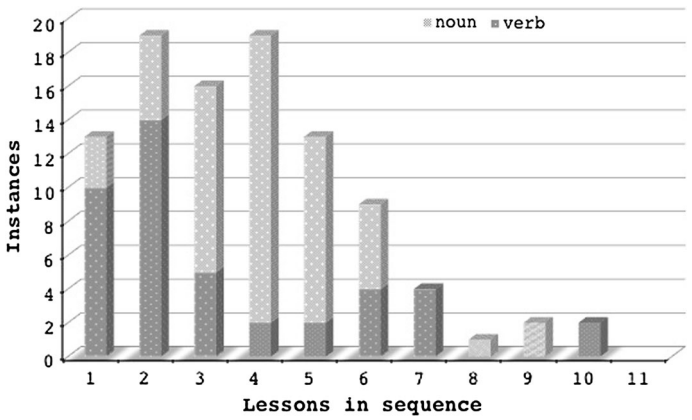

Fig. 2 Word use per lesson, words in groups

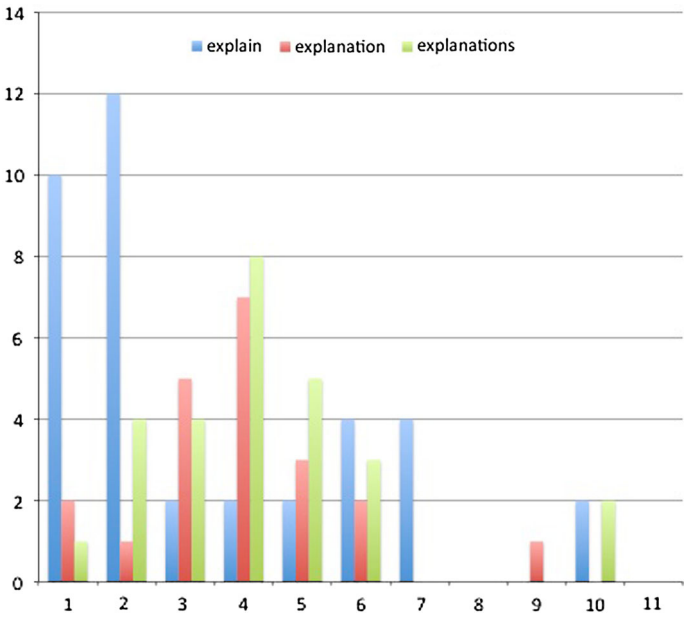

Fig. 3 Word use per lesson, selected words

in the frequent use of the word *explanations* during the first half of the lesson. The patterns in communication varied consistently according to how the organisation and interactional structure in each of the eleven lessons varied. Overall, the communicative approach could be described as interactive and dialogic (Mortimer and Scott 2003). Student groups were repeatedly given short tasks, for example students were supposed to discuss certain issues, such as acquired and genetic traits, the role of mutations, the development of the first living cell, and antibiotic resistance. These kinds of elements were present in ten out of eleven lessons in the unit. During peer-group work of this type, the teacher interacted with groups of students, answering questions, giving support and giving detailed instructions. The model of instruction has been described as between-desk-instruction by Clark and colleagues (2007). While the teacher was lecturing, students were allowed to ask questions and contribute to developing the various topics being discussed. In the context described above 98 instances of the targeted words were established in the teacher's talk.

The teacher asks for acts of explanation

Recurring patterns were apparent when the various forms of the words were used to denote *explanation* as a product and *explaining* as a process. Features of process were apparent in the use of the word *explain*.

The teacher makes directives to initiate work

The word *explain* was used as a directive in teacher-student dialogues to encourage students to take on the particular task but was embedded in talk so that it worked to motivate students as well as to create situations suitable for making formative assessments. Table 2 shows one example taken from the first lesson.

Table 2 Example: directive to students to make an effort

Notes on the whiteboard:
Why do giraffes have such a long neck? We believe that the giraffes of today, developed from giraffes with much shorter necks compared to giraffes of today? How come? Explain!

Macro context	Utterance	Instructional context	Micro context
L01T	Teacher: so what is your view on why giraffes have such a long neck? can you imagine what a giraffe looks like? you don't need to answer this now the giraffes of today are thought to, well they are relatives one could say to the giraffes that had slightly shorter necks, how did this happen?	Whole-class task-instruction	
0:24.13	**try to explain this** försök och förklara detta		Request-(acceptance)
	and now it is like this I don't want a sheet from all of you I want one sheet from you as a group group, okay?		

The utterance "*Try to explain this*" is addressed to the whole group of students and is preceded by an elaboration of the written instruction on the whiteboard. "*Try to explain this*" is a request for the students' contributions but the utterance is made in between talk about the background information written on the whiteboard and practical instructions about procedures. By using the word *try* the teacher indicates that she does not expect a correct explanation at this time. In the context, asking for an explanation means a request to the students' to formulate plausible connections between effects and causes concerning giraffes: "*how did the development of long necks come about*?". As a whole, the use of the word in the teacher's instructions works as a request but also serves to motivate students to accept and contribute. This way of using *explain* is understandable for a teacher striving to motivate students and at the same time wanting to be able to map students' learning on different occasions in the teaching sequence.

By using the word in this way the teacher asks for the students' articulations in ways that emphasize the process character of explanations at two levels: (1) *explaining* demands a certain amount of work and students are supposed to make this effort (2) *student-constructed explanations* are seen as providing momentary displays of a learning process extended over several lessons. In this use the word *explain* functions in relation to the further organisation of teaching, in terms of motivating and providing a conversational structure suitable for making formative assessments.

The co-construction of an explanation

The first excerpt shows an episode where teacher and student co-construct an explanation in the pedagogical–professional meaning of the word. The episode occurs about 40 min into the sixth lesson and less than 1 min after the students are instructed to work with study questions in the textbook. The questions are illustrated with pictures showing a white moose, an exercising boy and a cat with no tail and presented under the heading: "Develop your thoughts—Hereditary?". The conversation is initiated when one group of students request their teacher's assistance. Excerpt 1 shows 20-s of the conversation between teacher and students. During this episode the teacher leans with both arms resting on the table close to a textbook where the questions are displayed. The three students are sitting in a row along the table on the right-hand side of the teacher. Previous to this episode the

conversation concerns the exercising boy in the illustration. One student suggests that his babies would come out "really beefy". The conversation gives rise to laughter from both students and teacher.

Excerpt 1		L06T [0:42:31.6-0:42:50.9]
101	S	I think it is the moose that has °the greatest chance° of having white kids
102	T	Will it it will have white kids okay = why
103	S	=Greatest chance
104	T	=Why
105	S	=Cause it's
106	T	=Can you explai:n why
107	S	Cause it has not become white during life it has not been painted or anything
108	T	If you in fact had that trait
109	S	(Nods)
110	T	In ones cells is that what you are saying Martin
111	S	(Nods)

The task that students are introduced to concerns how to distinguish acquired and genetic origins of traits among visible characteristics of individuals, animals and humans. The word explain appears in line 106 in a particularly rapid sequence of the conversation. The preparation is made by two repetitions of the word "why", line 102 and 104. The student makes two starts in line 103 and 105 that are not acknowledged as answers. The teacher's emphasis and elongated "*can you explai:n why*" in line 106 is a sufficient elaboration of what is expected and prompts the student to give the contribution in line 107. The careful design of the utterance made in line 107, as a result of the dialogue, provides an effective way of establishing significant aspects of a valid explanation to the questions in this specific context. Here, the student exemplifies how the most probable explanation can be found through the process of falsification of other plausible explanations. The suggested falsification takes into account the white coloration as a trait acquired by the moose. The evaluation made by the teacher in lines 108 and 110, which takes into account the reasoning suggests one consequence. If the causes of the whiteness cannot be seen as acquired they may rather have genetic origins at the level of cells, as suggested in line 110. Seen in the context of Excerpt 1, the teacher's use of the word *explain* works to challenge students to develop formulations, thoughts and understanding regarding some phenomenon. The repeated why-question and accentuation of the word explain proves to be a strong tool for requesting students' articulations. The teacher draws conclusions and adds further constituents needed in the construction of a valid explanation in the particular situation. Excerpt 1 shows the joint construction of an explanation through teacher-student-dialogue, including some important constituents, such as driving force, sequential pattern and disciplinary derived logic.

The talk about what explanations are

Explanation and *explanations* are words that exhibit a product-nature obviously associated with their noun forms. In the teacher's word use, *explanation* is to a great extent associated with students' written products but also to ways of expression.

The teacher makes directives to induce comparisons

In a general sense the word *explanation* is used to denote particular ways of expressing oneself. In this particular classroom, explanations are also presented as being of different kinds when the teacher introduces classifications of explanations. First historical examples (the Bible, Lamarck and Darwin) are presented and then the teacher organises an exercise where the students classify each other's explanations according to the three historical examples, Tables 3 and 4. During these exercises, although explanations are treated as objects, they are used to produce a dynamic discourse about what explanations are. The communicative structure provides opportunities for the teacher to tell the students about epistemological expectations on scientific explanations and to mark key ideas about the form of explanations as well as providing the students with about how to evaluate and justify explanations.

Some of the concrete work of choosing the right words and phrases and distinguishing their interrelations in the production of an explanation is displayed in the communication. For example in the context of classifying students' explanations in the task about giraffes, the teacher says: "*the last the part in this explanation here, those have survived bad times because they reach that food*". While doing this she holds a piece of written text that the students have been working with and asks the students to check their own notes. This is a way of pointing to essential features of an explanation, and sharing these features between the participants. As part of a teaching strategy, this action makes features of explanations available, subject for discussion and opens the way for qualitative comparisons. When the teacher says: "*it is a bit like two explanations in one explanation*", the physical presence of the written product on the whiteboard in front of the teacher and students contributes to its meaning. The wording *"two explanations*" refers to two separate ways of explaining the same phenomenon, that is: to two ways of expressing relationships between events. The teacher deals with the function and form of one product and makes qualitative distinctions.

The teacher points to that an explanation is achieved in the relation between someone and something, Table 5. The question that the teacher poses to the students leaves several possibilities open for the students to respond to: "*how would he have explained this*?" or "*Lamarck would have liked to explain that as yes but do you think it is like that*?". The expressions depict the act of explaining as something that can be understood through some

Table 3 Example: directive to recapture distinctions

Macro context	Utterance	Instructional context	Micro Context
L04T	Teacher: yes tomorrow uhum it is like this you are going to work with your giraffe explanations today in your groups but to be able to do that we need to get back for a moment to where we were yesterday in the whole class	Recapturing of previous lesson in half-class	
0:08.55	**do you remember that we talked about different kinds of explanations of why life or why life develops why it looks, why life develops or why what is alive develops different traits?** kommer ni ihåg att vi pratade om olika sorters **förklaringar** till varför livet eller varför livet utvecklas varför det ser ut varför livet utvecklar eller det som är levande utvecklar olika egenskaper		Question-(answer)
	S: yes T: do you remember that we had got three different S: mmhmm		

Table 4 Example: directive to compare and discern differences

Notes on the whiteboard:
Try to classify the different explanations into the categories
1. Creationism
2. Darwinism
3.Lamarckism
4. murky/mix

Macro context	Utterance	Instructional context	Micro context
L04T	T: yesterday we had a discussion about whether one does not fit into any of the one, two or three (omitted lines) put them in a fourth and we will call that murky mix or something S: murky (giggles) T: yes right but	Task-instruction –half-class	
0:16.02	**try to find quotes that show that yes but this shows that this is this kind of explanation** försök å hitta citat som visar att ja men det här visar att det här är en sån här **förklaring**		Request (acceptance)

Table 5 Example: directive to take position

Macro context	Utterance	Instructional context	Micro Context
L07T	T: …and every do they all from the start all hares had this trait that they could change to white fur colour during winter time all of them got that? S: I have no idea about that T: what do you think? S: ehh maybe not T: life is a struggle and it is tough do they all have the same kind of traits S: but that's where Lamarckism comes up a bit because it like could have those rabbits who could not, they like that, they had a need	Whole-class discussion	
0:36.24	**T: mm that's how Lamarck would have liked to explain it yes but do you think it is like that?** T: mm hade Lamarck velat förklara det med ja men tror du att det är så?		Question-(answer)
	S: I prefer Darwinism Darwinism		
	T: I want you to use Darwinian theories to explain…		

underlying principles and reproduced as a display of personal opinions and issues of understanding. The example in Table 5 shows how the teacher frames the subjectivity of Lamarck, a famous biologist that presented theories about biological inheritance in the early 1800 century. The ending of the last utterance "*but do you think it is like that?"* infers truth as a feature for evaluation and opens up for a questioning of historical explanations as being true portrayals of reality. The teacher asks the student to take a position.

The teacher makes assertives for clarifications

The activities that the teacher organises involve working with students' written explanations, the three historical models and discussions about how the theory of evolution can explain issues in the real world, like biological variation or resistant bacteria. In the stream of discourse the teacher uses the word explanation to make distinctions and to clarify

teaching and learning goals, Tables 6 and 7. The expression *"not like it is really this way"* includes information about the teacher's view on a written product, which the student is supposed to acknowledge. The teacher makes it clear that at this point she is not talking about how the evolution of the giraffes' long necks really came about. When trying to

Table 6 Example: clarifying teacher's view on a written explanation

Notes on whiteboard:
Try to classify the different explanations into the categories
1. Creationsim
2. Darwinsim
3. Lamarckism
4. murky/mix

Macro context	Utterance	Instructional context	Micro context
L04T	T: and then it turns out that this part is Darwinistic then S: (reads) T: is it the nutrients that make that is it is it the fact that they eat that make their necks grow or what? S: I guess it is T: do they think	Peer-group Support	
0:29.22	**well we don't say that it is really this way but that it provides an explanation** här nu vi säger inte att det är så här utan det här är en förklaring		Assertive

Table 7 Example: clarifying teacher's purpose with task

Notes on the whiteboard:
Try to classify the different explanations into the categories
1. Creationism
2. Darwinism
3. Lamarckism

Macro context	Utterance	Instructional context	Micro context
L03T	T:(approaches group, deliver textbooks) but those you are only supposed to bring to future lessons and we will take that later check that later S: can I bring it home with me T: yes I want them in your bag S: mm T: mm okay are you all right with that	Peer-group support	
0:48.06	**when you say that it is either the first or second then I want you to say that it is because it is this in the explanation that makes us think that it it is like that** när ni säger att det är det är det ena eller det andra då vill jag att ni ska kunna säga att det är därför det är det här i **förklaringen** som gör att vi tänker att det är så		Assertive
	T: can you spot your own explanation? SS: yes T: what say S: we were Lamarckists T: yes S: no a mix or S: we were a bit of a mix T: a mix S: mostly Lamarkists T: yes but you recognize that now S: yes T: mm that's interesting (leaves)		

Table 8 Example: clarifying the role of evidence

Notes on the whiteboard:
Science knows that:
*The Earth is old -6000 years
-5 billion years

Macro context	Utterance	Instructional context	Micro context
L02T	Teacher: (writes on the whiteboard) compare 6000 years to 5 billion years S: did they believe it was 6000 years? T: yes think from the 17th century and back to 4004 before Christ that is about 6000 years …(talks about voyages of discovery during the 17th-18th centuries) T: (cont.)….they started to find what we today call fossils and that was very confusing because they could see that this looked like remains from old animals and some looked like the animals of today some did not look like the animals of today so you got you got something that confused what you had believed in before then	Lecturing	
0:10.38	**in the beginning one tried to explain this with the knowledge available they tried to fit this in with the biblical explanation that were the tools available** i början så försökte man förklara det med den kunskapen man hade man försökte få in det här I med biblisk förklaring det va de redskapen man hade		Assertive

understand the inherent logic in an explanation written by students, the teacher demonstrates the written product as eligible: "*but that it is an explanation*". Here, the teacher points to what an explanation does, and the way it should be understood in this context: as a piece of work by the student.

The strategy of bringing historical perspectives and contextual approaches to the understanding of evolution as the scientific explanation of life on earth recurs in the material, Table 8. This contributes to a view of scientific explanations as successively advancing socially-constructed knowledge. Saying "*one tried to explain with the knowledge available*" is evaluative and anticipates the development of science and scientific knowledge growth. The expression works to establish contrasts across contexts in that it compares the conditions for and the explanatory success of, early explanations to the work of students in this classroom. *Explain* is used in the example to make a statement about fossils as counterevidence to the biblical story of creation. It illustrates the human construction of explanations, as a response to what could possibly be perceived as the complexities of the real world. The statement clarifies the role of evidence in the development of scientific explanations.

The deconstruction of the biblical story of creation

The second excerpt is provided to show the sequential (de)construction of the biblical story of creation as a theoretical and explanatory model of the development of life on earth. During this conversation the everyday and the scientific meanings of the word explanation are at stake. Excerpt 2 is from the beginning of the fourth lesson. As part of task-instruction, the teacher reiterates what happened during the lesson some days ago: the presentation of the three historical models. Before the episode begins the teacher has written three words on the whiteboard: Creationism, Lamarckism, Darwinism, under the

heading Theories/explanations of the development of life. Now the teacher asks the students if they remember the three explanations of the evolution of life on earth that were previously presented. When no answers were offered the teacher allows the students to look in their notes and points to one of the words. The interaction is taking place in the classroom with the words Theories/Explanations written on the whiteboard.

Excerpt 2	L04T [0:09:32.8-0:10:20.1]		Teacher movements
201	T	Do you remember what this was↑	Points to the word Creationism
202	T	Creationism↑ which I won't say so much about right now↓	
203	T	(3.3) Robert(.)do you remember↑	
204	S	No	
205	T	(3.2)°Peter↑	
206	S	Well they believe it is god or or = the religious	
207	T	Yes = like the religi[ous]	Walks towards student
208	S	=[st]ory	
209	T	=Bi:blical like that↓ (1.1) do you remember that this	Nods, hand movements Underlines the word: Creationism
210		>What do you say < version (.) or theory tells that	Gesture
211		Everything is in fact ready-ma:de from the start so it is	
212		A bit difficult when I say that they develop↓	Points at the word: develops
213		That does not fit creationism = they would say = no(.)but	
214		Everything is ready-made↓(.)from the first beginning↓(.)	
215		>But we write < bi:blical anyway here (.) bi:blical	Writes
216		(.)Story of creation (.) > one way to < expla:in↓ (.) how	Turns to class
217		Life is↓(.)	

The episode starts when the teacher asks the question. Two nominations prepared by pauses, lines 203 and 205, follow before the student responds: "*well they believe like it is god* ". The teacher repeats and elaborates on the student response; meanwhile she looks at the student, takes a few steps ahead and at the same time is nodding and moving both hands in a weighing gesture. This enactment makes room for the student to add the word *"story",* in line 208. The pause in line 209 marks a point where the teacher turns from the student to the whiteboard and the three written words. The teacher continues: *"do you remember that this"* and underlines the word Creationism. The movement is a physical turning away from the students to the whiteboard but also represent a shift in the interactional structure. From elaborating on students' expected contributions the teacher turns to what is already written on the whiteboard and elaborates on that.

What the teacher says in lines 210–217 represents a condensation of complex information. This part is already prepared for in line 202 when the teacher says "*which I won't*

say so much about right now". First, in line 210: "*what do you say version or theory*" the emphasis on the word version is accompanied by the gesture of making quotation marks in the air with both hands. The preface "*what do you say*" shows how the teacher is searching for appropriate words. Both actions mark a distance to the words "theories/explanations" on the whiteboard. Second, in line 211 the characteristic of the model is given: "*everything is in fact ready-made from the start*" which gives rise to the teacher commenting on the word "*develop"* as problematic. Third, in lines 216–217 the teacher sums up by saying: "*biblical story of creation one way to explain how life is*". In this utterance the "*one way to*" is said quickly as a preface to the word: "*explain*". The last part: "*how life is*" seem to be the consequence of the established problematic relation between development and creation, in line 212. The teacher constructs the biblical story of creation as an explanatory model but a model that is not recognised as a valid explanation in this context. This (de)construction works by a series of formulations that draw attention to what is expected from a scientific explanation. This is where distinctions concerning expectations on a scientific explanation to the development of life on earth are made manifest. Development is presented as one criterion that is used to distinguish this theoretical model from a science-based model, although both are recognised to have some underlying theoretical principles. The teacher is clearly showing that the biblical story of creation does not fit into what is expected from an explanation. Still, it is used and denoted as such. Excerpt 2 is one example of a "double-take" on what an explanation means in this context.

The talk about students' constructed explanations

The organisation of teaching and learning activities gives rise to a multitude of situations where classroom interactions focus on characteristic properties of and distinguish commonalities and differences in ways of explaining.

The tools for evaluation

The subjectivity of explanations concerns the necessity for an explanation to be acknowledged as such by *someone.* In the material, this acknowledgement can be seen in specifying pronouns used by the teacher to connect the word explanation to an individual or a group of individuals, which depicts individuals as being owners or proprietors of explanations. Expressions like "*your*", "*his*" or "*each other's*" show how the teacher repeatedly strives to make students aware of and take part in justification and evaluation of classroom-constructed explanations. When saying: *"Lamarck had got his explanation"* the teacher uses an example from the history of science to provide students with a comparison to other subjective explanations. In the utterance about Lamarck, the teacher confronts students by saying that subjective judgement is needed to determine whether one explanation is more valid than another and evaluate correctness. The subjective judgement relies on the experience of understanding.

What the teacher presents in utterances such as those in Table 9, refers to explaining as part of a process of enquiry, whether in the classroom or in the history of science. In the work of getting students to evaluate explanations, the teacher refers to experience, senses and thought using words like "*feel*", *"catch*", and *"understand"*. By doing this, the teacher challenges the students to reflect on specificities in each explanation drawn on or exemplified. In other instances the teacher provides ideas for how evaluation of an explanation can be performed by referring to "*test*", "*fit*", "*discover"* and "*find"*. The suggested actions encourage students to reflect and can be understood as a way in which

Table 9 Expressions of evaluative actions, verbs emphasised

Macro context	Utterance	Instructional context	Micro-context
L10T 0:33.02	Start where you feel a bit comfortable and try to find explanations and so you will **test** the same explanations on the beans later	Peer-group instruction	Directive: request-(acceptance)
L03T 0:26.21	which of your the class's explanations **fit** into this one	Peer-group instruction	Directive: question-(answer)
L04T 0:40.11	I try my best to **find** good explanations	Peer-group instruction	Assertion
L04T 0:14.29	you will **discover** your own explanation	Peer-group instruction	Assertion
L04T 0:14.29	Is it a darwinistic explanation that this group has **given**	Peer-group instruction	Directive: question-(answer)

the teacher providing some conceptual tools in order to facilitate the work of evaluating and justifying explanations.

In the last example what can be seen as a predetermined yes or no question is an utterance that projects students' independent responses: "*is this explanation given by this group, a darwinian one"*. The teacher enables students to use the Darwinian theory of evolution as a tool in the evaluation of one classroom explanation. This action provides an opportunity for students to distance themselves from what is expected from an explanation at this point: the norm, and offers the chance to think and act and express their subjectivity.

The material also includes instances where a comparison is made between different levels of generalization. This is the case in one utterance taken from a whole-class summing-up activity during the fifth lesson: *"look here there are two theories in the same explanation"*. The use of the word theory distinguishes explanatory models in the formulations made by students and opens the way for discussions about the relation between (scientific) theories and (scientific) explanations. More explicit judgements of a normative character are found when the teacher says: "*but it is the beginning of an explanation"*. In this utterance the teacher positions students' work of constructing explanations as being different from its goal, the school scientific explanation. By doing this, the teacher enables an evaluation of students' current knowledge and skills as shown in the activity in relation to expected knowledge and skills as formulated in curricula. The expression *"but it is the beginning of"* recognises the student-constructed explanation as eligible in the pursuit of the correct explanation.

A talk about explanations

The third excerpt shows an episode where students, in dialogue with the teacher, talk about explanations, both in the everyday meaning of gaining understanding and in the pedagogical professional meaning of being able to provide correct responses to the question about the giraffe's neck. The episode is from a whole-class discussion in the fifth lesson.

Students have been working to find examples of the three presented model-explanations in students' constructed explanations. The word "*mixing*" in the teacher's initiation refers a conclusion made just before, that the constructed explanations seem to include elements from both Lamarck and Darwin. The question asked in lines 301–302 is a question with no known answer. When the teacher asks the question, she moves both her hands to her waist. Here, the students' understanding and perceived difficulties are made explicit and the topic for discussion (Swedish transcription and translation, see "Appendix").

Excerpt 3		L05T (0:21:40.1-
301	T	mm are you saying Adam ↑ (.) is it like that↓why is it like that = how come
302		That you are mixing in your explanations↑
303	S	Because I [eh]
304	T	[mm]
305	S	I think it's because you have heard maybe a bit about darwi[nism]
306	T	[mm]
307	S	=Although you still believe it is a bit like lamarckism = do you get it↑
308	T	mm mm that is this difficulty with the everyday understanding again

At a slow pace the student articulates a response in lines 303, 305 and 307, an action, which is supported by the teacher saying "*mm*", lines 304, 306. In the response Darwinism is presented as something known, while Lamarckism is a new concept: "*you have heard maybe a bit about Darwinism*". What the student expresses is the answer to why the students are combining the explanations: it is a mix of things they have heard about and things they have believed or thought about: "*although you still believe it's Lamarckism*". The emphasis on the words *heard* and *believe* creates a contrast between them. The utterance shows that this student recognised both models and what Lamarckism means in relation to Darwinism. The implied understanding represents a move towards acknowledging the pedagogical–professional meaning of the word explanation. A moment later the teacher nominates another student who continues:

Excerpt 3		Continued, (-0:22.35.5)
313	S	But maybe it is because you like want an ex explanation of why
314		It is like this like lamarckism is like well they needed to
315	T	Yes
316	S	And the the:n like you are like content a
317	T	Yes that feels almost like a nice explanation
318	S	Yes but darwinism is like a bit more like(1)well there is not quite
319		An explanation it is like just the way it is
320	T	mm and darwinism did not have genetics that's what we can say today=

The responsive property of lines 313–314 answers the teacher's question as to why students are mixing theories in their explanations. At the same time it is responsive to what was previously said in line 307, by anticipating the question: *why do people believe in*

Lamarckism?: "*it is because you like want an explanation of why*", line 313. The suggestion is that the Lamarckian way of reasoning gives an adequate answer to the why-question: "*they needed to and then you are like content*", lines 314, 316. Here, the teacher contributes to the continuation of the dialogue and gives support by taking turn offering one possible interpretation: "*yes that feels almost like a nice explanation*". The addition of the word "*almost"* is a disclosure. The Lamarckian way of reasoning is not really accepted as a valid explanation. In the following lines the student comments on the Darwinian way of reasoning: "*yes but Darwinism is like a bit more like well there is not quite an explanation*", lines 318–319. In the school context this dialogue opens for a characterisation of teleological explanations versus causal explanations: whether an explanation is expected to contribute to an understanding of why in terms of giving reasons behind purposeful behaviours of processes or phenomena. The teacher uses this opportunity to go on with the teaching and planned activities: lecturing about genetics. In this context the utterance: "*and Darwinism did not have genetics*", line 320, is responsive to what the student just said and it projects subsequent teaching activities. Saying this the teacher indicates that genetics is considered to be an important element in explaining the evolution of life on earth. Cell-structure, genetics and biological variation are recurring elements in the teaching sequence, which as a whole represents a comprehensible causal explanation for the evolution of life on earth.

The conclusions from this study of uses of "explanation"

The study contributes empirical examples of one teacher's uses of the words "*explain*" and "*explanation*" in the context of teaching about biological evolution. The approach illuminates how disciplinary norms of valid explanations are made manifest in communication in the science classroom. The focus on word use adopted in this study proved to be fruitful in the sense that recorded situations provide insight into the teacher's guidance and instructions on how to take on the challenge of explaining, justifying and evaluating explanations. Some conclusions regarding the coexistence of the three word meanings, the literature about explanations and the dialogic approach will now follow.

The co-existing word meanings

The empirical analysis provided indicates that three potential meanings of the words *explanation* and *explain* have an influence on epistemic, structural and evaluative applications in science education. Excerpt 2 includes a "double-take" on the meaning of explanation. The word "double-take" is used to designate the teacher's action simultaneously addressing two features of explanations: as theoretical models and causal representations of sequential events. In the evaluation of a creationist model as a causal representation the teacher pays attention to the word "develop" as being inconsistent with the creationist model. Excerpt 3 shows an episode where students' difficulties and perceived understandings are made the topic for the conversation. The communication between teacher and students illuminates the close connection between the words *explanation* and *understanding*. In the conversation articulations oscillate between projecting an everyday meaning of the word explanation and a pedagogical–professional meaning of the word. The kind of dialogue where students articulate and reflect on their own understandings of explanations provides opportunities for learning but also for the teacher to

evaluate and assess. Excerpt 1 shows how the word explain constitutes the driving force in a traditional IRE/IRF structure for the articulation of a more elaborate school science explanation.

The conversational structures

Empirical examples are provided of how the teacher in various instructional contexts looks for students' reflections and provides conceptual tools to facilitate the work of evaluating and justifying explanations. The teacher approaches this by framing conversational structures. *Asking for acts of explaining* provides one conversational structure. In the material, the questions where students are asked to explain are embedded in instructions or teacher-student dialogues. This produces questions that turn out to create situations suitable for making formative assessments about students' learning and the progression of the curricular unit. A second structure is the *talk about what explanations are*. Here, essential features of explanations are made available to participants, subject for discussion and open for qualitative comparisons. This seem to be the kind of conversation that Osborne and Patterson (2011) promote in their paper. Their discussion and the clarifications provided by Braaten and Windschitl (2011) are vital for the development of teaching approaches suitable for teaching about what explanations are. A third structure, is the organisation of activities that turn into platforms for *talk about students' constructed explanations*. This is a structure for interaction provided for the articulation of students' perceived difficulties. Excerpt 3 is an example where classroom communication explicitly addresses the co-existence of evaluative and sense-making processes. The students in Excerpt 3 articulate reflections on their own learning processes thereby making them available for evaluations in relation to teaching and learning goals. The interaction that takes place is oriented to a meta level and fits the goals of articulation and sense-making described by Berland and Reiser (2009). This kind of exchanges give opportunities to develop social aspects of science and science learning, in ways that have been articulated as important by, for example, Berland and McNeill (2012). The conversation in Excerpt 3 pictures the role of *explaining* as one active component of students' learning processes while *understanding* constitutes the end point. This conclusion is close to the suggestion by Ford and Wargo (2012): understanding represents the outcome of education.

The conceptual confusions in the literature

In an attempt to contribute to clarifications I will describe my understanding of the three papers by Osborne and Patterson (2011), Braaten and Windschitl (2011) and Berland and McNeill (2012). The concerns articulated by Osborne and Patterson (2011) point to conceptual confusions due to diverging approaches to the role of epistemological and social aspects in the study of explanations. The view represented here is that there is a possibility that this conceptual confusion to some extent depends on different conceptualisations of the three notions of the word explanation: everyday, pedagogical–professional and scientific. According to this view the three papers work to define and establish the interrelations between the three meanings of the word. The papers by Osborne and Patterson (2011) and Braaten and Windschitl (2011) primarily explore the relation between the *scientific meaning* of explanation and the *pedagogical–professional* meaning of the word. Berland and McNeill (2012) primarily explore the relation between the *pedagogical–professional* meaning of the word and the *everyday meaning* of the word.

The three potential meanings of the words *explanation* and *explain* remain a communicative challenge for teachers and students. For science teachers, the pedagogical–professional meaning of the word explanation together with the everyday meaning and the scientific meaning of the word are available as resources in communication with students. What the dialogical analysis gives insight into is how the teacher and students use gestures, emphasis and sequentiality in dialogue, to accomplish mutual understandings of the meaning of *explanation*. If teachers and researchers become more aware of the three potential meanings of the word explanation it could introduce opportunities for a more conscious use of the word, which would benefit learners, teachers and researchers alike.

The discussion about *explanation* and *argumentation* has a long history. An explanation can be provided as an answer to a question, as shown in Excerpt 1, an explanation can also be part of an *argument-dialogue game* (Antaki and Leudar 1992) which takes place in a communicative context. The emphasis in this paper is on how the three communicative traditions of everyday life, the pedagogical–professional context in schools and the context of science, influence the use of language in science education. Consequently what a certain communicative act means in science education varies from situation to situation. This could be true for argumentation too. However, compared to explanations, the more recent introduction of argumentation in science education, for example in the publication by Rosalind Driver, Paul Newton and Osborne (2000), speaks for a less developed tradition: a shorter history and less well-defined pedagogical–professional meaning of the word. Therefore, what argumentation means ought to vary between the communicative traditions of everyday life and science, and be less well-defined in the pedagogical–professional context. Future investigations into theoretical and practical uses of this term could bring still more clarity to the field.

Understanding teaching and learning about biological evolution

The study approaches the lesson sequence as a number of constituent elements and their interrelated dynamics. The analysed episodes and overview of the lesson sequence inform about instructional context and the sequential interlinking of elements, in terms of school science textbook knowledge. Between elements such as cell-structure and reproduction, phylogenetic and biological variation, a number of connections are made across historical accounts and the details of scientific facts. Over the course of the sequence this is developed into descriptions about events in the history of science and the historical reconstruction of the development of life on earth. The explanation of the evolution of life therefore constitutes the whole of the teaching unit and cannot be in an appropriate way reduced.

The close relation between *understanding* and *explanation* discussed in the paper might introduce particular complexities for teaching and learning about biological evolution. The scientific way of explaining biological evolution through historical evidence and theoretical models of genetic variation and reproduction does not seem to meet students' requirements with regard to gaining further understanding. In the material, one student expresses this:"*well there is not quite an explanation it is like just the way it is*". The close similarities between how the words *explanation* and *understanding* are used in an everyday sense also introduce certain expectations about scientific explanations. Scientific explanations on the other hand are developed to meet other expectations and requirements. This

difference could be explicitly addressed in the teaching of evolution as well as in science teaching more generally.

Final comments

The structure of the teaching sequence in the classroom being studied here had apparent similarities to the second part in the MUSE unit, as described in Ford and Wargo (2012). In the MUSE unit, three historical models were presented to students. Activities included the reading of original excerpts written by Paley, Lamarck and Darwin and making comparisons and accounting for speciation. In the present study, three explanations for the evolution of life were represented: Creationism, Lamarckism and Darwinism. The representation was in the form of the teacher writing short texts on the whiteboard. Students' comparisons of underlying assumptions were attributed to students' own writings using the three explanations as theoretical models. While the teacher developed the design of this sequence prior to the study any similarities found between the two studies is coincidental.

Finally, in this study, language is seen as a culturally-developing tool for communication. Long traditions of using language to convey meanings in many different communicative situations influence the use of words and the ways of expressing that can be observed for example in science classrooms. Word use in institutional settings such as classrooms must therefore not only be regarded as a display of the knowledge held by participants or their individual cognitive abilities. Teachers and students activate available language resources in their communication that essentially constitutes teaching and learning of science. This means that culturally established ways of using and not using language resources are pointed to and made manifest. The dialogical perspective in the analysis takes this into account. It is not of interest for the purpose of this study to look for reasons for word use that are based on individual abilities or capabilities connected only to individual participants in the study. This paper represents one attempt to contribute to a deeper understanding of how traditions of using language in science education influence on-going work of teachers and students and in that sense our understanding of prevailing conditions for the teaching and learning of school science.

Appendix

Transcript conventions

301	Numbering of the lines in each transcript to facilitate reference to specific utterances or actions in text
↑↓	Rising and falling shifts in intonation are indicated by up- and down-pointing arrows
=But look here	'Equals' signs mark the immediate 'latching' of successive talk
[]	Square brackets mark the start and end of overlapping speech aligned in transcript to mark the precise position of overlap
Underlining	Indicate emphasis
°I think so°	'Degree' signs enclose hearably quiter speech
(0.8)	Numbers in round brackets measure pauses in seconds (in this case, 8 tenth of a second)
(.)	A micropause
[(Looks at screen)]	Additional comments, used for denoting of gestures and moves
Because e::	Colons show degree of elongation of the prior sound

Overview of lesson sequence

Curricular unit: biological evolution						
Lessons (50 min)	1	2	3	4	5	6
Addressed topics	Evolution as topic in science class, How do particular traits develop? Assignment about giraffes' long necks	The development of life on earth presented by giving an historical account of the development of life on earth, from big-bang to today	Historical models of the evolution of life, categorisation task	Historical models of the evolution of life, categorisation task	Commenting on previous events. Cell structure and DNA.	Why do we have a variety of attributes and characteristics? Reproduction of DNA in cell cycle.
Activity structure	1.Introduction 2.'Brainstorming' 3. Instruction 4. Group assign 1	1. Summary 2. Lecture 3. Whole class discussion	Repeated half class: 1. Summary 2. Instruction 3. Assign 2	Repeated half class: 1. Summary 2. Instruction 3. Assign 2	1. Comment 2. Lecture 3. Small group discussion	1. Summary 2. Lecture 3. Small group discussion 4. Instruction
Tasks and questions	Evolution and genetics: what do you think about when you see those words? Assignment 1: Why do giraffes have such a long neck? We believe that the giraffes of today, stem from giraffes with much shorter necks compared to giraffes of today? How come explain!	What did the world look like millions of years ago? And what will it look like millions of years ahead? Three different explanations for the development of life on earth: Creationism, Lamarckism, Darwinism	The three different explanations as goals for students learning during sequence. Assignment 2: Try to classify the different explanations into the categories Creationism, Lamarckism Darwinism	The three different explanations as goals for students learning during sequence. Assignment 2: Try to classify the different explanations into the categories Creationism, Lamarckism Darwinism	What was the difficult part when trying to classify and sort the different explanations into the three categories?, Are mutations good or bad, what does it depend on whether good or bad?	Will you hand over your mutation to your own kids? Instruction: Assignment 3 what happens with the offspring of cat with no tail, body builder and white elk—will offspring inherit traits?

Overview of lesson sequence

Curricular unit: biological evolution					
Lessons (50 min)	7	8	9	10	11
Addressed topics	Follow up. The development of life on earth. Phylogenetic tree.	Conditions for development of first living cells. Miller's experiment on creating life.	Practical activity including beans and beakers. Instruction in textbook.	Practical activity including beans and beakers. Instruction in textbook.	Individual and population. Traits, DNA and explaining variation. What is eugenics? What are resistant bacteria?
Activity structure	1. Summary 2. Assign 3 3. Lecture	1. Introduction 2. Lecture 3. Small group discussion 4. Lecture	Repeated half-class 1. Instruction 2. Task work 3. Summary	Repeated half-class 1. Instruction 2. Task work 3. Summary	1. Introduction 2. Lecture 3. Small group discussion
Tasks and questions	Assignment 3 what happens with the offspring of cat with no tail, body builder and white elk—will offspring inherit traits?	What happened between primeval soup and the appearance of the first living bacteria? What bacteria will survive and why these?	Describe the characters of one bean, mix with other beans in the beaker, try to use the explanation to find the proper bean	Describe the characters of one bean, mix with other beans in the beaker, try to use the explanation to find the proper bean	How come that the variation among a species is so big?

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