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Animation and grammar in science education: Learners' construal of animated educational software

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Abstract This case study reports on how students, working collaboratively, interpret and construct a written report of the events described in animated educational software. The analysis is based on video recordings of two upper-secondary-school students while they are endeavouring to construe an animated sequence of the mouldering process. How the students grammatically construct their written account by means of available semiotic resources (i.e., animation and educational text) provided by the software is investigated. The results show that attentionally detected features of the animation take the role of active subjects in the students' description of the animated phenomena. When framing their sentences, the students derive noun phrases from animated active subjects and from the educational text. In the students' efforts to express themselves in their own words, they use verbs that differ from the educational text. These two actions together contribute to giving the students' description of the process a character of a non-scientific explanation. Lacking relevant subject matter knowledge, the students cannot judge whether they have given an adequate account or not. The only way that the students have to appraise their written report is to check if it is grammatically correct. It is concluded that it is essential to consider both cultural and semiotic processes when designing technology-supported educational approaches to the teaching of scientific concepts.

Keywords Computer animation · Educational software · Interaction analysis · Science education

Introduction

Biochemical processes occur at a micro level that is impossible to observe ocularly. This fact poses a considerable problem for educators, who have to demonstrate such invisible events in ways that can be conceptualised by students. To explain and make these

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unobservable phenomena understandable, scientists and science educators strive to depict these microscopic phenomena in ways that make them visible. Such models are mere representations of scientific concepts and it is of vital importance for science educators to gain an insight into how learners understand the phenomenon illustrated. Mostly, the only account of students' conceptualisation is a verbal or written statement. Often, students do not present an explanation that is in line with the intended learning outcome and, hence, not in accordance with canonical science. Such unintended interpretations made by the students are referred to as misconceptions (e.g., Cañal 1999; Kuech et al. 2003; Morton et al. 2008) or erroneous ideas (e.g., Sanders 1993). Most often educators do not know how, or why, some ideas arise that are not in accordance with scientific knowledge. One way of unravelling students' comprehension of scientific concepts which are introduced is by making a close inspection of their reasoning about observed phenomena.

Aim of study

The analysed material comes from a study that aims to investigate how secondary-school students make use of and construe computer-animated biochemical processes in the carbon cycle. In this article, a case study is reported that aims to examine how two students manage to complete a written report of a biochemical process that is depicted in computer-animated software. The analysis includes how the students grammatically construct their written account of what is happening in the animated processes by means of their available semiotic resources. By analysing the reasoning and interaction taking place when groups of students collaborate in studying a set of animations, the study aspires to gain insight into students' interpretations of the depicted processes. The close relationship between language and thinking (Vygotsky 1934/1986) and the socioconstructivistic perspective form the basis of the study and analysis. This epistemological standpoint is discussed in a sociocultural approach where discourse and knowledge are mediated by tools and constituted in a social practice (Säljö 1998; Wertsch 1991).

Earlier research

To understand the circulation of matter in the carbon cycle, it is important to realize that air contains matter in the form of gases such as oxygen and carbon dioxide. Research, though, has shown that students do not imagine air as matter (e.g., Smith et al. 1997). "Because students think that matter is something that they can see, touch and feel, they have problems conceiving of gases as matter" (Smith et al. 1997, p. 799). From an educational point of view, one way of making it possible for students to envisage gases as matter may be by visualising events of gas molecules involved in the gas exchange between organic materials.

Students are more likely than professionals to think of models as physical copies of reality rather than as constructed representations that may embody different theoretical perspectives (Grosslight et al. 1991). Nevertheless, a model assumes a connection between the depicted phenomena and reality that requires the observer to make an association to the real world. As Chittleborough et al. (2005) point out: "the use of any model requires the learner to identify the analogue (the model) with the target (reality)" because "without the learner making this connection, the model has no value" (p. 196). When examining how professional chemists and chemistry students (i.e., novices) responded to a variety of chemistry representations, including animations, Kozma and Russell (1997) found that the surface feature of the display was attended to by both experts and novices. The difference though, was that while the chemists focused on underlying concepts and principles, the students seemed to be constrained by the media and their surface features.

In a study of how students extracted information from animated weather maps, Lowe (1999) revealed that the processing of animations is driven by dynamic effects and that "much of the information extracted was perceptually salient rather than thematically relevant" (p. 225). Lowe (2003) also found that compared with static graphics, the inclusion of temporal change in a visual display introduces additional processing demands. This implies that experts, for example, designers of illustrations for science education and teachers, might not see the same thing in the graphics as a novice. As Krange and Ludvigsen (2008) remark in their study of a computer-based 3D model for teaching molecular concepts to secondary-school students:

> In complex knowledge domains, like the one studied here, the meaning potentials carry a history that is often invisible to the students. This knowledge domain is constructed over extensive periods of time, and only a small part of it is inscribed in the tools. This means that the students only get access to the top of the iceberg of this knowledge base, and what part of this that they manage to realise in practice is an empirical question. (p. 29)

Consequently, a major concern for designers and educators must be to gain knowledge of the ways that students construe and make meaning out of multimedia learning tools representing scientific phenomena.

Expressing events linguistically

Learning from experiencing a multimedia event also requires the learner to transform the observed phenomenon linguistically. Halliday (2004) contends that from early childhood, our experiences are transformed into meaning, and this transformation is affected by the grammar of our language, "grammar transforms experience into meaning" (p. 11). "Understanding and knowing are semiotic processes—processes of the development of meaning in the brain of every individual, and the powerhouse for such processes is the grammar" (Halliday 2004, p.11). Thus, according to Halliday, to understand something is to transform it linguistically into meaning and the result is what we refer to as knowledge. Bakhtin (1986), on the other hand, stressed the dialogical perspective on humans' meaning-making processes and contended that "the relation to meaning is always dialogic" and that "even understanding itself is dialogic" (p.121). Bearing in mind these views, I would instead argue that when we use grammar in a communicative process, our experiences are structured in certain ways.

Lemke (1990) argues that scientific language is a special genre and constitutes a particular way of talking about the world. Scientific language displays some specific features through "a preference in its grammar for using the passive voice" and a "grammatical preference for using abstract nouns derived from verbs instead of the verbs themselves" (Lemke 1990, p. 130). This way of describing occurrences, in the passive form and with the usage of nouns instead of verbs, is not what students are used to in other areas. This may result in students finding science hard to understand and might discourage them from pursuing science (Lemke 1990). The specialised language of science, thus, has implications for how students view the subject (Lemke 1990; Halliday 2004).

When having to describe a scientific phenomenon linguistically, the students face the problem of describing the events in writing. "The sentence in its basic structure consists of

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a verb and one or more noun phrases, each associated with the verb in a particular case relationship" (Fillmore 1968, p. 21). According to Fillmore, these "noun phrases" are associated with the verb in a particular case relationship:

> The case notions comprise a set of universal, presumably innate, concepts which identify certain types of judgements human beings are capable of making about the events that are going on around them, judgements about such matters as who did it, whom it happened to, and what got changed. (p. 24)

Consequently, the problem of lexical selection of verbs and nouns for insertion in a sentence depends on particular arrays of such cases.[1] "In lexical entries for verbs, abbreviated statements, so-called 'frame features' will indicate the set of case frames into which the given verbs may be inserted" (Fillmore 1968, p 27). In the frame feature for a verb like "move," it is necessary to specify an object such as a "stone"; the sentence will then be "The stone moved." There are also optional elements to be included in the frame feature for the verb "move" as an "animate subject" and an "instrument phrase" as in the sentence: "He moved the stone with a lever" where "He" represents the "animate subject" and the "lever" the "instrument."

Tomlin (1997) investigated how conceptual representations of visual events are mapped into language, and argues that we should start by looking at the "attentional focus." He proposes that when viewing a dynamic event "some component is 'attentionally detected' at any given moment in time and that this allocation of attention is pre-linguistic" (Tomlin 1997, p. 171). As regards the temporality in dynamic events and its consequences for language construction, Tomlin argues:

> Finally, it is essential to keep in mind that conceptual representations are dynamic in nature. Events are witnessed rapidly and in real time. It is conventional to think of propositional representations as somehow enduring or atemporal and that informational statuses associated with components of the propositions—topic status, focus status, referential status—also endure and are atemporal. But we will argue here that grammars look directly at event representations during language production, so the temporality of those representations most assuredly matters. (p. 171)

An utterance describing the events is then formulated lexically where the grammar identifies the attentionally detected parameter "and it maps just that parameter onto syntactic subject" (Tomlin 1997, p. 172). In an experiment, where observers were presented with a set of animated sequences, Tomlin (1997) showed that "speakers do assign a focally attended referent to the syntactic subject in English as they formulate their sentence for production" (p. 179). Without cueing objects, "large size or animacy may simply result in a particular attentional detection, and it is this which is mapped onto subject" (Tomlin 1997, p. 182).

Methods

In the study reported here, the students were supposed to linguistically describe the events they could observe in the animated sequences on a computer screen. Animation for educational purposes is still in its infancy as a teaching aid and needs to be addressed in educational research. The question is then how to do research on complex media artefacts

[1] For classification of cases that need to be included, see Fillmore (1968, p. 26–27).

from which students make diverse meanings depending on their different backgrounds. Lemke (2006) proposes that: "We replace an input-output model with a 'tracer' model. We open the black box of intermediations that lie between any input and any output and we follow or trace in detail the actual processes by which outcomes are arrived at" (p. 9). Applying such a research strategy will, of course, not offer a general theory of how simulated or animated multimedia presentations will be construed by students in an educational setting. Instead, case studies of learning situations involving educational artefacts should provide insight into trajectories of students' reasoning when endeavouring to make meaning of the observed representation (Lemke 2006).

Understanding how representations are used and construed in a learning situation requires studies of multimodal recourses used by the learners such as talk, gestures, and gazes, when interacting with the representative tool and each other. When we socially organise ways of seeing and understanding events, Goodwin (1994) demonstrates the practice of "highlighting" which work to make "specific phenomena in a complex perceptual field salient by marking them in some fashion" (p. 606).

The way students talk about the depicted processes can give us an insight into students' conceptualisation of the knowledge domain because "the mastery of science is mainly a matter of learning how to talk about science" (Lemke 1990, p. 153). Language, however, is not the only semiotic resource that is used in meaning-making processes between humans. Instead, a variety of multimodal resources such as intonation and all kinds of body language combine to form an integrated system for communication (e.g., Lemke 1998, 2006).

To address this problem of representing the variety of semiotic resources used by the students when interacting with each other and the interface, that is, the computer screen, I have chosen to demonstrate the analysed episodes by employing a mode borrowed from comics. This style—also referred to as sequential art (Eisner 1985; McCloud 1994)—of representing the analysed material allows us to show image shots from the video segments connected in strips to demonstrate the unfolding character of, and sequentiality in, the students' interaction. I believe this style, as argued elsewhere (Ivarsson 2010), to be a productive mode for visually presenting the learners' multimodal conduct when working with a representational tool. Like all modes for re-presenting audiovisual material in printed form, sequential art inevitably lacks some of the information on the original videotape. When presenting the episodes as strips of frames with speech bubbles, you lose information available in a traditional Conversation Analysis (CA) transcript such as intonation, pausing, overlapping speech, and so forth. Q2

Interaction analysis of knowledge building in small groups is an emerging and promising method in the area of CSCL.

> Group learning has a qualitative advantage over individual learning. It is not just that two minds are quantitatively better than one or that the whole has a Gestalt that exceeds the sum of its parts. The synergy of collaboration arises from the tension of different perspectives and interpretations. During discourse, a meaning is constructed at the unit of the group as utterances from different participants build on each other and achieve an evolving meaning. (Stahl 2006, p. 299)

Wegerif (2007) contends that students learn to think better in groups by learning to listen to each other and to question their own initial ideas. Thus, Wegerif proposes a dialogic framework for teaching, using CSCL where reflective dialogues are seen as an end in themselves. Teasley and Roschelle (1998) argue that the essential advantage of collaborative problem solving is that it enables the construction of a shared conceptual structure, which they call a Joint Problem Space that "supports problem solving activity by integrating semantic interpretations of goals, features, operators and methods" (p. 2). They contend that the use of the computer screen as a shared focus for learning that occurs socially contributes an important resource that mediates collaboration. Studying dyads of students using a dynamic computer simulation of a model of velocity and acceleration, they conclude that "in ordinary circumstances, one cannot imagine two 15 year olds sitting down for 45 min to construct a rich shared understanding" (p. 26). Concerning the learners' capacity to jointly create meaning of a simulated phenomenon, the authors contend that their study "demonstrates that students have powerful resources for constructing shared knowledge" (p.28).

Adhering to my research interest in how students collaboratively construe meaning in a computer-supported environment, I will apply a "dialogic" research approach (Arnseth and Ludvigsen 2006), where the analytical concern is primarily the problem of how the computer application provides a framework for students' interaction. By viewing understanding and cognition as socially constructed and distributed among the participants in an ongoing activity, I attempt to give details of the events in a multimodal communication that result in the participants' shared explanation. When analysing human-computer interaction (HCI), Greiffenhagen and Watson (2007) found that the focus is not just on the interlocutors' problems in understanding each other, it is more on what they are supposed to achieve in the activity. In the study reported in this article, the students endeavour to construct a cooperative description of what the computerised animations are illustrating. Studying how learners come to agree on a text describing the observed computer-simulated model enables us to gain an insight into the meaning-making processes taking place in the student-student interaction and in the student-interface relations.

Research design

This study constitutes the second part of a design experiment (Brown 1992) where topics of the educational sequences in the carbon cycle are studied in learning settings. In the first study (Karlsson and Ivarsson 2008), a computer-animated program was designed and tested in a science course. The educational application[2] includes animations visualising gas exchanges in biochemical processes in the carbon cycle. In four processes—photosynthesis, breathing, combustion, and mouldering—animated sequences depict gas molecules either being absorbed or emitted. The index page shows an educational text, describing the main outlines of the carbon cycle and a menu where one can choose between pages describing each process. The Web pages for each process are furnished with an explanatory text and a link to an animated sequence of the events. The application is interactive in the sense that the user can choose in which order to view the processes and play the animated sequences. This enables the students to replay and freely explore the animations and captioned Web pages.

In the initial study, there was no special tutorial introduction of the topic before the students started their exploration of the animations. The students were just given brief instructions about how to manage and navigate in the learning environment. The analysis of the first study revealed that the students faced problems in interpreting and drawing conclusions from the animated sequences. Observed problems were the risk of students focusing their attention on misleading aspects of the animation and the occurrence of

[2] Available at: http://www.init.ituniv.se/~gorkar

isolated reasoning within each of the processes. As a way of addressing some of these problems, a new lesson plan was drawn up containing an elaborated introduction to the knowledge area. In the subsequent study—accounted for in this article—the same application was used but the introduction to the subject field was more exhaustive. Before the students started working with the application, they attended a 1-h lesson dealing with the processes in the carbon cycle. The aim of the introductory lesson was to provide the students with more knowledge of the subject in order to facilitate their construal of what was happening in the processes depicted. Another problem revealed in the initial study was the students' varying understanding of what resources they were expected to use when performing a given task. The students' assignment was formulated as: *"Explain in your own words what you can see happening in the different animations."* This formulation proved to be troublesome for some of the groups as there were conflicting ideas among the members about what they were supposed to describe in their written answer. Were they just to describe what they actually could see happening in the animated sequences, and thereby disregard their previous knowledge and what they could read in the text captioning the animations? Or were they to give an account of what they really knew about what happened in the processes? Even though the question was intended to make the students draw their own conclusions from the animation and not just copy the text, the formulation, in fact, created increased uncertainty about how to accomplish their task. In view of this, it seemed important in this second study to pay attention to the formulation of the assignments that the students were going to perform. Accordingly, in this subsequent study, the students' assignment was simply expressed as: "*Explain what is happening in the different processes that the animations are describing.*" This was to avoid the conflict situation and allow the students to utilise all available resources when describing what is happening in the animated processes.

The study was conducted in a Swedish upper secondary school where students in four classes, attending a course in natural sciences, participated. The course, dealing with basic scientific issues, was attended by 12 boys and 53 girls aged 16–18 years. Three of the four classes consisted of students enrolled in aesthetic student programs, which accounts for the large proportion of girls. The fourth group of students was enrolled in a science program and consisted of 9 boys and 10 girls. Prior to the work with the animations, all classes had a lesson with their teacher dealing with the processes in the carbon cycle. The students were instructed to work in dyads, or in a few cases, in triads with the task of interpreting what was happening in the animated sequences.

Just before starting their exploration of the animations, the participants were given a brief introduction for about 10 min, instructing them about where to find the website and how to work with the learning application. The groups were then provided with an assignment sheet requesting them to explain what was happening in the four processes depicted in the animated sequences: photosynthesis, breathing, combustion, and mouldering. It was presented as a joint assignment where they had to discuss, reflect, and compare their different views within the groups. The time allotted for completing the assignment was 30 min but most groups only used about 20 min for their discussion and completion of the assignment sheet.

Video recordings were made of seven randomly selected groups, five from aesthetic programs and two from the science program. The seven groups were videotaped during the entire session while they were carrying out their assignment of construing the animations. The video recordings were analysed to gain an understanding of how the students interpreted their tasks and made meaning out of what they observed in the animation. In accordance with Jordan and Henderson's (1995) prescription for interaction analysis, I started by identifying what was analytically interesting in the video-recorded material. Next, the whole data corpus was checked to see whether the generalizations were valid. The segments selected were then viewed and discussed in an interdisciplinary work group of researchers. All text in the software as well as the communication was in Swedish and has been translated into English by the author.

Results

A general feature throughout the seven video-recorded groups analysed was the students' efforts to create written accounts about what was happening in the animated sequences. The students engaged in creating a joint description and explaining in colloquial terms what was shown in the animations. As an example of how the animations were interpreted and formulated in text, the reasoning of two female students, attending an aesthetic program, is discussed in the following analysis. The girls were video recorded during their entire session working with the learning application but the analysis will focus on the part where they endeavour to explain what is happening in the mouldering process.

The educational text

At the top of the Web page, describing the mouldering process, there is an educational text that says:

> Dead plants and animals are attacked by microorganisms. These decomposers utilise the energy in the carbon compounds for their own energy consumption. With the release of energy, the decomposers use oxygen in the air that combines with the carbon in the carbon compounds and forms carbon dioxide. When mouldering, oxygen is consumed and carbon dioxide is produced.

Underneath the text, there is an image of a decaying log on the ground, linking to the animation of the mouldering process. In the animated sequence, oxygen molecules are seen approaching the decaying log from the side and when reaching the log, carbon dioxide molecules are seen leaving the log. After a while, the log darkens and collapses. The students switched between the window showing the animation and the introduction page where they could read the explanatory text.

The students' written report

In the questionnaire where the students were asked to explain what was happening in the mouldering process, the two girls wrote:

> Oxygen surrounds the tree and is attacked by microorganisms. Carbon compounds are mixed in and form carbon dioxide that is let out. Mouldering produces carbon dioxide.

This answer does not meet the standards of current canonical science. Consequently, their teacher did not approve of their written account and commented:

> They demonstrate a great lack of knowledge; they only have some understanding of mouldering.

The teacher was also quite bemused by the students' formulations and, in addition, remarked:

> Do they really mean that oxygen is attacked by microorganisms? Where are the carbon atoms mixed, in a pot or what? I am very uncertain whether they have understood that it is the micro-organisms that do the job.

From only reading the girls' account, one could conclude that they have not paid enough attention to the question or put enough effort into trying to work out a satisfying explanation and that they have, therefore, given an inadequate answer. By means of a close inspection of the video-recorded material, I want to retrace the events that eventually led to the students' written account. The analysis aspires to uncover how the students' conclusions were produced and negotiated as a consequence of their interactional work. Important questions that will be pursued are what their line of reasoning was and how they constructed their written report. The data proved to appear in discernible sections and are presented in four parts where the two students at first try to: find out a causality in the animated sequence (episodes 1–2), then construe the meaning of the educational text (episode 3), formulate their own report of what is happening in the mouldering process (episodes 4–6), and finally assess their written account (episode 7).

Finding out what is happening

In the opening episode, the girls have already gone through the first three processes in the carbon cycle and begin watching the animation of the mouldering process. In the sequence, they can witness the oxygen molecules moving toward the log on the ground.

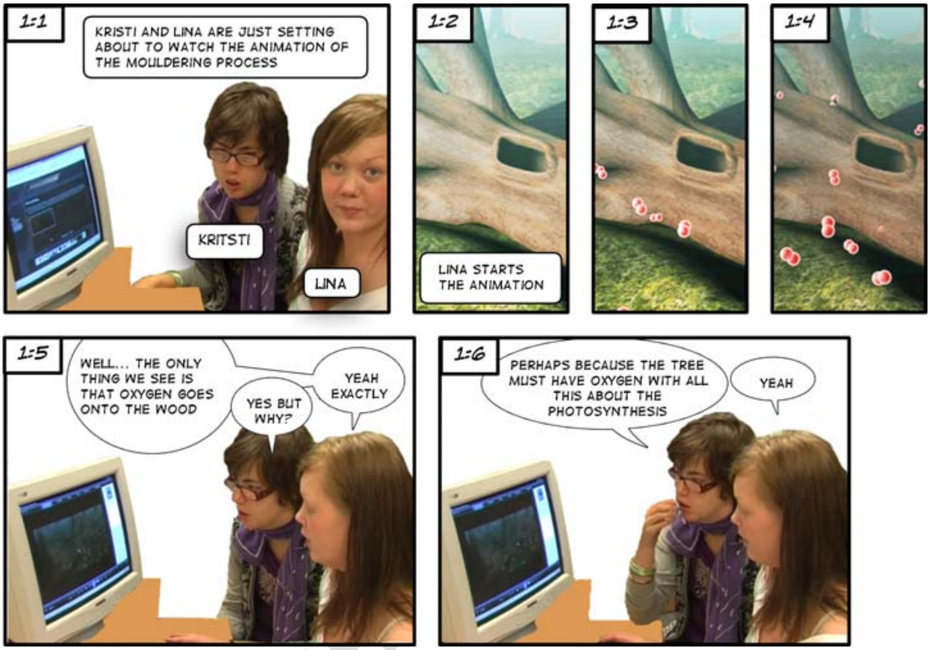
Episode 1

This episode, from the girls' initial encounter with the animated sequence of the mouldering process, reveals several confusing parts for them to deal with in their interpretation of what is happening. After observing the animation, Lina remarks (panel 1:5) that "the only thing we see is that oxygen goes onto the wood." With this remark, Lina has assigned the oxygen molecules an "active" role, thus making them an agent in the event. As a consequence of being "attentionally detected," the oxygen molecules are "assigned to subject" (Tomlin p. 178).

Kristi's utterance in the last frame that "the tree must have oxygen with all this about the photosynthesis," appears to be troublesome for some reason. They are now examining the mouldering process and not photosynthesis, which is visualised in a separate sequence and which they have already described. Another problematic fact is that in photosynthesis, it is carbon dioxide that is assimilated and oxygen that is emitted. Furthermore, "the tree" referred to is the decaying log on the ground and because only the green parts of a living plant photosynthesise, a decaying log cannot be part of the process. However, what seems most important to Kristi is finding an explanation of the movement of oxygen molecules toward the log.

During the girls' work with the animation, it is noticeable how they try to find cause, effect, and sequentiality in their discussion about what is happening in the animated process. The first thing they observed in the animation of the mouldering process was the oxygen molecules moving toward the log. These molecules from now on constitute a core agent in their effort to give a description of what is happening in the animation.

After some computer problems, Lina restarts the animation. The conversational turns concerning the reloading problem have been omitted and in the next episode, we continue to follow the girls' discussion about what is happening when the oxygen molecules reach the log.

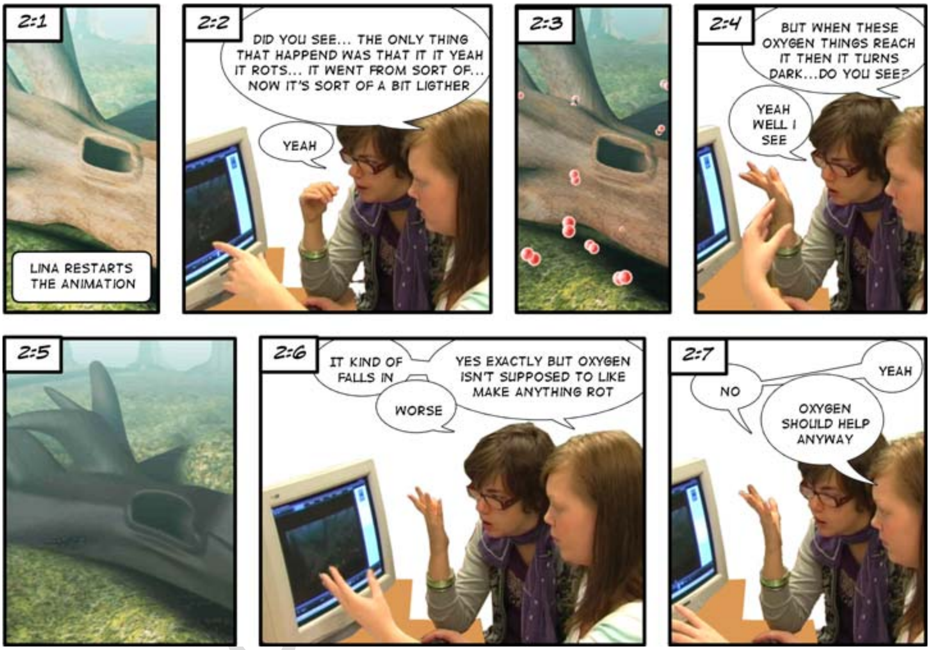


Episode 2

When they watch the animation a second time, Lina notes (2:2) that initially the log is light brown. She points at the screen where the log is visible in order to get her partner's attention to what she is talking about. Lina also remarks (2:4) that it is when the oxygen molecules "reach" the log that it turns dark and collapses. This remark implies that a temporality is imposed on the process, which means that it is not until the oxygen molecules reach the log that it starts decaying. Kristi agrees with Lina's observations but at the same time produces a gesture of puzzlement (2:4) to accompany her talk. In panel (2:6), Kristi utters the word "worse" to describe what happens to the log when it darkens and collapses. While Lina mirrors Kristi's gesture, she articulates the problematic aspect of the observation by uttering "oxygen isn't supposed to like make anything rot." With this utterance, a conflict is established concerning what seems to be happening in the animation and what she thinks will happen. Lina continues with "oxygen should help anyway" (2:7) and Kristi agrees.

Lina construes her own observation of the animated sequence as oxygen being the agent, seemingly causing the log to rot. This conclusion puzzles her and, in some way, contradicts her concept of oxygen as something that "shouldn't kind of make anything rot" and should instead "help." The students' interpretation of oxygen causing decay contradicts their preconception of oxygen as being required for the vital process of breathing and, hence, something "life giving."

It is noteworthy that they do not comment on the carbon dioxide and do not seem to notice these molecules leaving the log. The students' attention seems to be focused on the oxygen molecules and their effect on the log. In the animation, oxygen molecules first appear to move toward the log and only after a while are the carbon dioxide molecules seen emerging from the log. In the girls' interpretation of the animation, oxygen molecules are, as the first "attentionally detected" objects, taken to be the active agent, directing their description of what is happening in the animation.



Construing the educational text

Apparently, in an attempt to find an explanation of their bewildering finding that oxygen causes the log to rot, Lina minimises the window displaying the animation to be able to read the text describing the mouldering process. The girls look at the text and Lina reads it out loud while Kristi reads it silently.

Episode 3

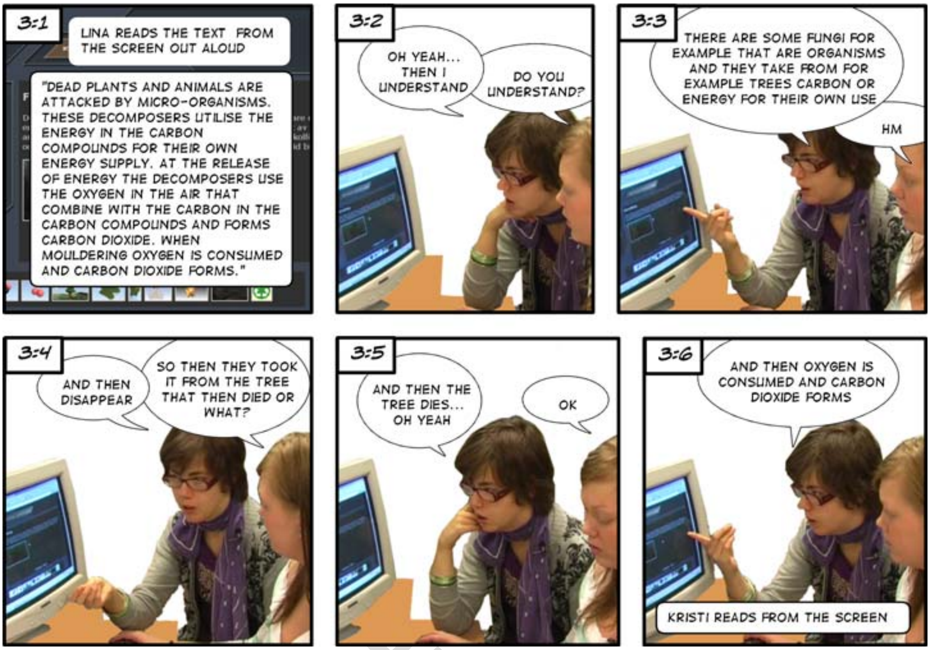
When the girls have finished reading the text, Kristi, in panel 3:2, exclaims, "then I understand." What she understands or means by understanding is not obvious. As a response, Lina asks in an astonished tone "do you understand." Lina's question is sequentially and anaphorically linked to Kristi's utterance about understanding.

Kristi, in the next panel (3:3), replies to Lina's question by making an effort to explicate the text by expressing it in her own words: "that there sort of are some fungi for example that are organisms and they take from, for example, trees, carbon or energy for their own use." This is a rephrasing of the first two sentences in the educational text that says: "Dead plants and animals are attacked by micro-organisms. These decomposers utilise the energy in the carbon compounds for their own energy consumption." With her explanation, Kristi shows that she regards Lina's question "do you understand" as an indication that she, for her part, did not understand and as a request for a clarification of the meaning of the text. The girls' "formulations of understanding or lack of understanding are used to discern and articulate problems" (Lindwall 2008, p. 248).

Kristi displays her "understanding" by reformulating the educational text in her own words and by mentioning "fungi" as an example of what a decomposer might be. The text only refers to microorganisms as decomposers but does not specify what kind of organisms they might be. In her explanation, Kristi shows that she obviously has some pre-knowledge of fungi being decomposing microorganisms. By using the expression "they take," she gives an everyday description of what is expressed in the text as "utilise." In her view, the concept of "utilise" seems to be equivalent to something being "taken." The term "utilise" used in the text implicates an agency in the process that Kristi transforms into the even more active term "take." Kristi's purpose of this transformation of the rather scientific word "utilise" could be to make it easier for her partner to grasp the meaning but it might also be a function of the students' ambition to express themselves in "their own words," as will be discussed later. Kristi also clarifies by using the example of "trees" instead of the text's somewhat imprecise wording "Dead plants and animals." The animation depicting a log lying on the ground may facilitate the connection to "trees" rather than other dead organisms as mentioned in the educational text. Kristi then says that fungi take "carbon or energy" from "trees," thereby separating carbon and energy into two entities, although the text says that: "decomposers utilise the energy in the carbon compounds." It has not been clarified for her by the text that energy is chemically bound in the carbon compounds and she describes energy and carbon as two separate entities. Kristi's claim, that she understands can, therefore, not be said to be completely in accordance with the scientific text.

After listening to her companion's explanation in panel 3:3, Lina utters a "hm." Kristi's reply, "and then disappear" (3:4), indicates that she perceives Lina's "hm" as indicating that she has not quite grasped the meaning of her explanation and needs more clarification. Kristi's utterance "and then disappear" is a paraphrasing of what the text describes as "the release of energy." The expression "the release of energy" is rather vague—meaning the transformation from one form of energy into another—and Kristi replaces "release" with the word "disappear." Again, we can see Kristi transforming a word from the educational text into her own expression. In response to this, Lina says "so then they took it from the tree that died then or what." What she is referring to with "they took it" is not obvious but can be seen as an attempt to make a causal connection between something that takes something from the tree, and what caused the death of the tree. The educational text does not mention anything about what caused the death of the tree and Lina's utterance suggests that she is trying to find a reason for the death of the tree. Kristi's reply, "and then the tree dies oh yea" (3:5), confirms Lina's suggestion and can be seen as a reaction to the ending of the utterance with an "or," requiring a response. Lina verifies that she follows her partners reasoning by saying: "OK." Kristi, in the last panel (3:6), then points at the final sentence in the text and reads out loud "then oxygen is consumed and carbon dioxide is formed," thus bringing to an end their exploration of the educational text.

In this episode, the girls have discussed what the text means and they seem to have grasped the intended meaning, namely that microorganisms consume carbon compounds for their energy supply; in this process, consuming oxygen and forming carbon dioxide.



Formulating their own account

The assignment directs the students to write down an account of what they can see happening in the animated sequence. In the following episodes, we will follow how they strive to formulate this written account of the events in the mouldering process.

Episode 4

With the utterance "shall we say so" in the first panel, Lina tacitly ratifies the explanation collaboratively constructed in the previous episode. Her proposal also transitions the activity into composing their report. Then she points at the trunk on the still image with a rotating gesture and utters "it was therefore oxygen went in there," apparently referring to the animated oxygen molecules reaching the log. Then she turns back to the text and finds the phrase "attacked by microorganisms" which she utters as a suggestion to be added to the observation of the oxygen molecules reaching the log. Kristi confirms this by saying "yeah we can write that." Thus, according to this description, the oxygen molecules go into the log and are there attacked by microorganisms. The girls' attempt to combine what they have observed in the animation with the wording in the text has radically changed the content of the educational text.

Oxygen molecules are perceptually salient in the animated sequence—neither microorganisms nor carbon hydrates can be observed in the animation—and becomes prominent when Lina constructs a story about what is happening in the process. She then takes the phrase, "attacked by microorganisms" from the text where it is used to describe the microorganisms' consumption of energy-rich carbon hydrates from the tree. Using this phrase as a subordinate clause to the observation that oxygen goes onto the log, produces the meaning that it is the oxygen molecules that are being attacked by microorganisms instead of carbon hydrates as described in the educational text. The verb "attacked" is not an invention by the student as it appears in the educational text; however, when reused together with the observation from the animation, it creates a new meaning.

Lina, in panel 4:2, turns to the educational text, points at the last phrase: "carbon dioxide is produced," and proposes the formulation, "then it becomes carbon dioxide." Lina, by using the word "then" establishes a temporal order to the process. The expression "carbon dioxide is produced" in the educational text is scientific language with a passive form. This way of describing a natural phenomenon in a passive metaphoric form is uncommon in everyday spoken language where something is caused by a preceding event (Halliday 2004). In other words, the students recast in a direct way what the text expresses with a "grammatical metaphor" (Halliday 2004, p. 19).

Lina again brings up the problem of formulating a written account by saying "how are we going to write this then" (4:3). After some consideration, she utters the word "oxygen" (4:4) and starts writing it down in the questionnaire. Kristi utters the verb "goes in" but Lina changes to the verb "surround" when she says, "yeah oxygen surrounds the tree." For Lina, replacing the verb is obviously not a problem as she says "yeah" before her utterance, implying that "surrounds" has the same meaning as "goes in." Kristi accepts changing the verb without any protest. We can observe that once the agent subject (oxygen) has been agreed on, changing the verb is not an issue for the students. In episode 1 and panel 1:5, it was proposed that "oxygen goes onto," while in this episode it is changed to "oxygen goes into" and "oxygen surrounds." This change of verb, though not problematic from a syntactic point of view, semantically implies that the subject "oxygen" is given a different agency (Duranti 2004).

In panel 4:5, Lina directs her attention to the educational text, points to the first sentence, and quotes the phrase, "attacked by microorganisms." The text says: "Dead plants and animals are attacked by microorganisms." Lina, however, only quotes the second part of the sentence, "attacked by microorganisms" to link it with their observation of the moving oxygen molecules. Kristi says "yes that sounds good" (4:6), agreeing with Lina's suggestion. Lina then writes down their first sentence: "*Oxygen surrounds the tree and is attacked by microorganisms*." It is noteworthy that the first clause in the sentence is given an active form: "*Oxygen surrounds the tree*" whereas the subordinate clause, "*is attacked by microorganisms*" is in the passive form. What they have visually observed in the animation is described in active form but the formulation derived from the educational text appears in its passive form. The active form in the main clause can be explained based on the assumption that when the agent (oxygen) is the subject, the clause is active (Tomlin 1997). Their subordinate clause, however, is taken from a scientific text where natural phenomena are often described in the passive form (Lemke 1990; Halliday 2004).

It can be observed in panels 4:1, 4:2, and 4:5 how Lina uses pointing gestures with her pen to make salient, for her companion, what features on the interface to attend to while she is speaking. This practice of "highlighting" structures of relevance on the screen can be seen as a method "used to divide a domain of scrutiny into a figure and a ground, so that events relevant to the activity of the moment stand out" (Goodwin 1994, p. 610).

After completing their first sentence, the girls try to find out what else is happening in the process by once again scrutinising the educational text. In the next episode, we will follow their endeavour to reach a conclusion about what is happening in the mouldering process.

Episode 5

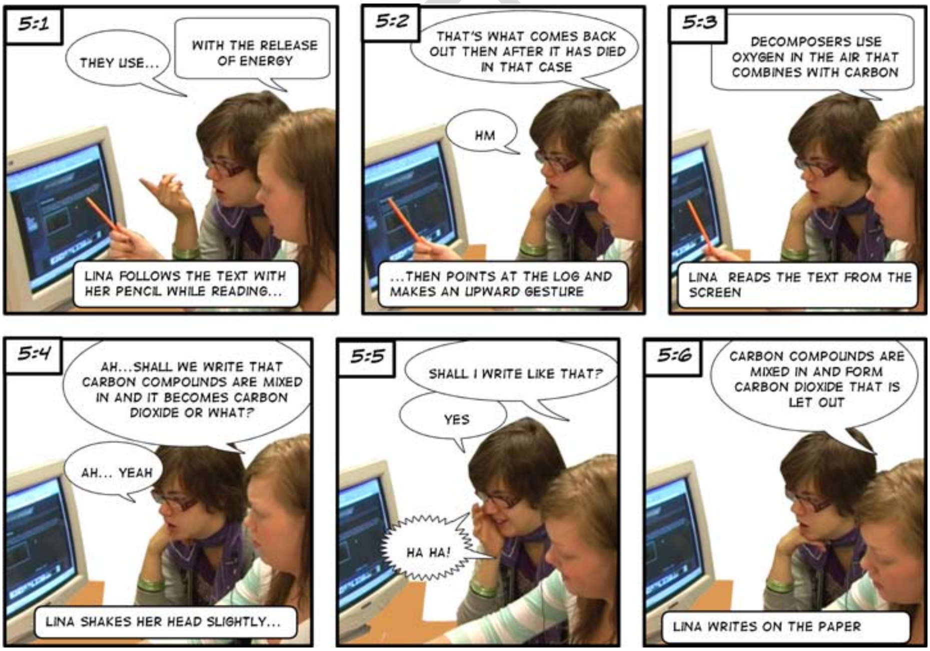
At first, both girls read the text silently with Lina following the lines with her pencil. Kristi suddenly points at the phrase: "these decomposers utilise" and exclaims "they use." Lina, however, does not follow up on her companion's utterance and instead quotes the phrase "with the release of energy" from the text. In panel 5:2, she shifts her pencil from the text to the image of the decaying log and, with an upward gesture, demonstrates that something is coming out of the log and says: "that's what comes back out then after it has died." To an outside observer, it is not obvious what she means by "comes back"; whether she is referring to the "release of energy" in her previous remark or if she means the carbon dioxide shown emanating from the log in the animation. Lina's upward gesture with her pencil resembles the movement of the carbon dioxide in the animated sequence, which suggests that the animated structure is transplanted into iconic gesturing, describing what is happening in the process.

Lina then (5:3) continues to read the text on the screen: "decomposers use oxygen in the air that combines with the carbon." After some contemplation, she asks, "shall we write that carbon compounds are mixed in and they become carbon dioxide" (5:4). With this suggestion, she reformulates in her own words what is expressed in the text as "combines with" as, "are mixed in." The term "combines" is a rather abstract expression that involves a combination of at least two entities; in the educational text, referring to chemical bonding. Lina's expression "mixed in" is, on the other hand, a plainer and more everyday phrase that simply means that you bring things together. The replacement of the verb "combines" with "mixed in" results in a change in meaning. This tendency, by the students, to replace verbs in the educational text with their everyday expressions results in the meaning of the text changing.

For the students, who do not have access to the relevant subject knowledge, this changed meaning resulting from the replacement of the verb may not be obvious but results in their description diverging from a scientific explanation. In the scientific text, the forming of carbon dioxide is described in the passive form and it is noticeable that Lina's proposed formulation "carbon compounds are mixed in" is also constructed in the passive form. The usage of the passive form is a special feature of scientific language (Halliday 2004; Lemke 1990) that distinguishes it from colloquial language which describes events as causalities in an active form. However, there seems to be some disbelief in Lina's proposal, which can be discerned in her ending her utterance with "or what" and slightly shaking her head.

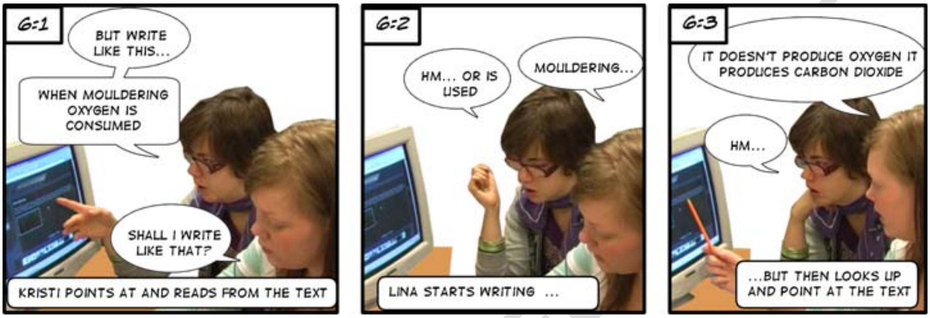
Even though Kristi agrees, Lina disbelievingly asks again if she should "write like that" (5:5) whereupon Kristi again expresses her approval. After some laughing by both girls, Lina starts writing on the assignment sheet and says "carbon compounds are mixed in and form carbon dioxide that is let out" (5:6). With this description of "carbon dioxide that is let out," it is now evident that with the upward movement by her pencil in panel 5:2, Lina was referring to the carbon dioxide depicted in the animation as coming out of the log. Hence, what is described in the educational text as the process, "form carbon dioxide," becomes "let out" in Lina's interpretation of the animated molecules leaving the log. Her observation of the animated carbon dioxide molecules is given priority over the formulation in the educational text when she writes the report on the events.

While Lina is still concentrating on writing, Kristi again focuses her attention on the text by pointing at the screen.



Episode 6

Kristi reads aloud from the text on the screen and suggests that they should write: "when mouldering oxygen is consumed." Lina responds by asking "shall I write like that." Kristi seems to perceive Lina's question as a problem of formulation and suggests rephrasing it by substituting the word "consumed" with her own expression "used" (6:2). Lina starts writing the word "mouldering" but suddenly looks up, points at the text (6:3), and raises the objection that "it doesn't produce oxygen it produces carbon dioxide." This could be seen as a strange comment on her companion's proposal of the formulation that "oxygen is used." Probably Lina is so involved in writing that she does not pay attention to Kristi's proposed formulation and misunderstands its meaning.



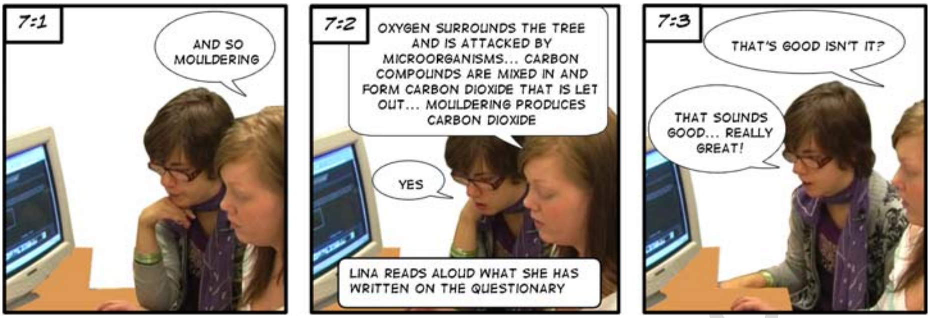
A really good account

The girls then read through their written accounts of all the processes again, finally coming back to the mouldering process. The conversational turns when they go through the other processes have been omitted and we join them again when they return to their account of what is happening in the mouldering process.

Episode 7

In panel 7:2, Lina reads out loud what she has written down on their assignment sheet about what is happening in the mouldering process: "*Oxygen surrounds the tree and is attacked by microorganisms. Carbon compounds are mixed in and form carbon dioxide that is let out. Mouldering produces carbon dioxide.*" We can now witness the formulation of the last sentence she has written in the questionnaire: *"Mouldering produce carbon dioxide."* The formulation of this phrase was discussed by the girls in the previous episode but was not put into words by Lina until now. If we compare the formulation of Lina's sentence with the educational text: "When mouldering, oxygen is consumed and carbon dioxide is produced," we observe that the phrase "oxygen is consumed" is omitted. Kristi wanted to reformulate this expression as oxygen "is used" (6:2), however, Lina did not include the phrase "consumption of oxygen" in the account. Kristi nevertheless backs up Lina's formulation of their narrative by saying "yes" (7:2). Another observation that can be made is that what the educational text describes in the passive form: "carbon dioxide is produced," the students describe in the active form: *"Mouldering produce carbon dioxide."* Again, we can observe the difference between the scientific passive form of grammatically describing an event with the students' description in the active form (Lemke, 1990).

Lina finally asks, "that's good isn't it" (7:3) to which Kristi answers "that sounds good, really good." Thus, the girls seem to be very satisfied with their account and this closes their dealings with describing the events in the mouldering process.



Discussion

Taken together, the excerpts analysed give a picture of how the two students endeavour to find the logic in what is shown in the animation, matching it with the educational text, and creating a story that makes sense from their point of view. They strive to make meaning out of the animation as well as the text and fit these two representations together in a written report.

Interpreting the animation and translating the educational text

The students start their interpretation of what is happening in the animated sequence by watching the oxygen molecules moving toward the decaying log. They also observe that when the oxygen molecules reach the log, it turns dark. We can follow their descriptions of oxygen as the active agent throughout their discussion: in panel 1:5 "*oxygen goes onto the wood,*" 2:4 "*but when those oxygen things reach it then it turns dark,*" 2:6 "*yea exactly but oxygen shouldn't kind of get anything to rot,*" 2:7 "*oxygen should help anyway*" and "*oxygen that went in there,*" 4:4 "*goes in*" (referring to oxygen) and "*oxygen surrounds the tree.*" The perceptually salient features of the oxygen molecules being in motion attract the students' attention and the information they derive from the animation is driven by this dynamic effect (Lowe 1999, 2003). Thus, the oxygen molecules become the active agent around which they create their narrative.

In the girls' attempts to explain what they observe in the animation, they turn to the educational text and try to construe it in a way that corresponds with what they observe in the animation. They read the text mostly silently but sometimes aloud, presumably when they want to stress something. In their effort to construct a story about what is happening in the mouldering process, they repeatedly strive to reformulate, in their own words, what is written in the educational text.

The students were supposed to explain what is happening in the different processes, but instead of telling their own story of what was happening in the mouldering process, their actions turned out to make it a task of translating the given educational text into their own words. In the data, we can find various types of evidence that the girls engage in translation rather than telling their own story of what is happening in the mouldering process. First, they attend to the given sentences one by one, and while dealing with a particular sentence, they attend to its different elements in a similar step-by-step manner. Second, they collapse the second and the third sentences from the educational text into one. Third, because of the disconnected character of the girl's sentences, for example, it is not at all clear whether the objects of the first sentence play any role in the second. Finally, in the follow-up interview where the girls were asked why they changed the words of the original text, one of the girls explicitly announced that it was to "show that we had done the assignment." The students' assignment was to explain what is happening in the mouldering process that was described in the educational software. Within the learning material, the animation and the educational text were the available resources for the students to draw on when accomplishing this assignment. Together with their observations from the animation of oxygen "surrounding" the trunk and with carbon dioxide "coming out" from it, the girls might have assumed that matching these observations with a translation of the educational text (assumed to give a correct description of the events) would result in the accomplishment of their task.

In a preliminary study (Karlsson and Ivarsson 2008), it was shown how conflicting perspectives among the students aroused concerns regarding how to formulate their reports. These conflicting perspectives were, to some extent, supposed to stem from the formulation of their task, where it was stated that they should express themselves in their own words. The assignment for the students in this study did not state that they had to use their own words in their written account. Nevertheless, we can observe how the students attempt to find expressions that are dissimilar from the ones in the educational text and more in accordance with their own way of articulating the events. Even though we did not see the conflicting perspectives which are observed in the preliminary study on what kinds of resources the students were going to use, they tried to find their own expressions, not using the wordings in the educational text. This aspiration to express themselves in their own words influences their written account. When the girls were subsequently asked why they tried to find their own expressions instead of using the formulations in the educational text, their respective answers were: "*I wanted to express myself in my own words. I always try to use my own words in my answers*" (Kristi) and "*I think I reformulated the answer because if I wrote exactly as it said in the text on the computer I was afraid it wouldn't count as an answer, but cribbing so to speak. It wouldn't have shown that we had done the assignment even if what we did was just to reformulate it. I guess that's the reason*" (Lina). These statements express an underlying norm of articulating themselves in their own words when they are supposed to give an account in a school context, consequently there are "certain cultural conventions when approaching and solving tasks" (Lund and Rasmussen 2008, p. 409).

The animation and the educational text together describe the mouldering process in two quite different modes; the animation by demonstrating moving molecules and the text by using scientific language. Both of these modes describe the metabolism occurring inside microorganisms. The students' meaning-making process is taking place in their attempt to grammatically construct a narrative from two different semiotic resources. With the help of the educational text, they then strive to explain in their everyday language what they can see happening in the animation.

Framing their sentences

When the students begin writing their report, they start with: "*Oxygen surrounds the tree.*" Being perceptually salient, the oxygen molecules first caught their attention. To find a cause of this motion toward the log, the students turn to the text and find the phrase "*attacked by microorganisms,*" which becomes the second clause. Their first sentence is then: "*Oxygen* *surrounds the tree and is attacked by microorganisms.*" If we look at how the students have grammatically constructed their narrative of what is happening in the animated sequence, oxygen is ascribed the role of the active semantic agent that "surrounds the tree" and then "is attacked" by microorganisms.

The main clause "*Oxygen surrounds the tree*" is framed by an "agentive" instigator (oxygen) of the action and an "objective" (the tree) affected by the action. Hence, the *noun phrases*, "oxygen" and "the tree" are associated in their specific case relationship, in the frame feature for the verb "surround" (Fillmore 1968). However, this description is not in accordance with the wording in the captioning text where it says that: "Dead plants and animals are attacked by microorganisms." The animate microorganisms are described in the educational text as the active subject, attacking dead materials. In the students' construal of the animation, the inanimate oxygen molecules take over the role of an active subject from the animate microorganisms. This shift of agency and subject role, from the animate "microorganisms" to the inanimate "oxygen," can be attributed to two different phenomena: first, the character of the animation that makes the oxygen molecules perceptually salient, and second, the grammatical rules in Swedish (as well as in English) that allow inanimate objects to be given an agentive status. As expressed by Duranti (2004), "we should take into consideration the possibility that, by representing actions and events typically generated by human beings *as if* they were generated by inanimate objects or abstract sources, English speakers might be giving these non-human entities a quasi-agentive status" (p. 464).

Hence, the character of the animation furnishes the otherwise inanimate oxygen molecules with an active role as they are observed moving toward the log. Contrary to real events in nature, an animation can provide inanimate objects with qualities such as motion and directionality. In the animated sequence, the oxygen molecules are given locomotive power as well as a directional course owing to the visualisation of a scientific phenomenon. In addition, the temporality of the events in the animation, where simultaneous events are sequentialised and oxygen appears as the first moving object, makes them prominent (Lowe 2003). Thus, events that occur simultaneously tend to be visualised in sequence due to the unfolding character of the animation. These qualities of the animation taken together make the oxygen molecules active and "attentionally detected" and, therefore, the subject (Tomlin 1997, p. 175) in the students' description.

In their first sentence, "*Oxygen surrounds the tree and is attacked by microorganisms,*" the students copied the subordinate clause "*is attacked by microorganisms"* from the educational text where the word "attacked" refers to the microorganisms' consumption of energy-rich carbon hydrates in organic material. This phrase fits grammatically into the sentence frame (Fillmore 1968), however, with this construction, the phrase "*is attacked by microorganisms*" refers to the inorganic "oxygen." The term "attacked" is, in itself, problematic when used in an educational text as it implies agency in the phenomenon described. On the one hand, from an educational point of view, it communicates the microorganisms' process of breaking down carbon hydrates into organic matter. On the other hand, the agency implied by the term "attacked" is unintentionally taken up by the students to describe what happens to the oxygen molecules. Thus, the students' construction of the sentence results in an unintended description of what is happening in the process.

The students' formulation of the second sentence: "*Carbon compounds are mixed in and form carbon dioxide that is let out,*" like their first sentence, would not be acceptable from a scientific point of view. In their construction of this sentence, the girls looked through the educational text and from the sentence, "With the release of energy, the decomposers use oxygen in the air that combines with the carbon in the carbon compounds and forms carbon dioxide," they picked out the noun "carbon compounds" that were given the subject role. Having chosen the subject, they continued and tried to find a verb describing what happens to the "carbon compounds." In the same sentence in the educational text, they found "combines" that they reformulated as "mixed in." They had then formulated their main clause: "*Carbon compounds are mixed in.*" When forming the subordinate clause, they took the phrase "and form carbon dioxide" from the same sentence in the educational text. This phrase was then combined with the verb "let out," which was derived from the students' construal of the animation where carbon dioxide molecules were seen leaving the log. Their sentence was then completed as "*Carbon compounds are mixed in and form carbon dioxide that is let out.*" This second sentence also fits into a sentence frame although it does not give an explanation of the event that can be in accordance with a scientific description.

When constructing their narrative about what happens in the process, the students strive to find a noun phrase (NP) that is followed by a verb that fits into a sentence frame. "In English, when present, the NP with the Agent role is typically chosen to be the subject" (Duranti 2004. p. 460). In the students' effort to use their own words, they try to find verbs that are different from the ones in the educational text. Grammatical rules allow the verb to be changed within the sentence frame (Fillmore 1968; Duranti 2004). However, in the process of changing the verb, they may also alter the agency of the subject. These courses of action together contribute to giving the students' report on what happens in the mouldering process the character of a non-scientific explanation. Lacking definite access to the relevant subject matter knowledge, the students consequently cannot judge whether they have given an acceptable account. The only way they have to appraise their written report is to check if it "sounds good," which they do by reading through their written report. By using noun phrases, taken either from the animation or from the educational text as agentive subjects and with self-constructed verbs, they created a grammatically correct, although not scientifically correct, written report of the mouldering process.

The students judged their account of the depicted process to be "good" or even "really good," which made them satisfied with their task. The analysis shows that the students have actually made an effort when constructing a shared meaning and writing a comprehensible report. Seen from the students' point of view and with the resources available to them, they created an acceptable narrative of the events described in the software. However, according to their teacher's judgment "they demonstrate a great lack of knowledge" and "they only have some understanding of mouldering." Before their work with the animation, the two girls said that they were "not at all good at science and that stuff." They will certainly be disappointed when they learn of their teacher's criticism of their account. This criticism will probably also reinforce their conviction that they are not good at science and that science is a difficult topic to understand. Consequently, providing students with animations of scientific phenomena and giving them the task of discovering scientific processes without sufficient guidance, may run the risk of leading them away from the intended learning outcome and giving them the impression that science is a difficult subject and hard to master.

"Size and animacy (or at least motion) represent—completely independent of language—characteristics of objects which attract attention" (Tomlin 1997, p. 182). When having to represent the animated event, "large size or animacy may simply result in a particular attentional detection, and it is this which is mapped onto subject" (Tomlin 1997, p. 182). In the students' construal of the animation, the animacy of the gas molecules, especially the oxygen molecules, influenced their description of the events. This feature of the animation resulted in the oxygen molecules as agent subjects becoming more or less fixed, giving less freedom to create innovative explanations. Instead, the freedom to construct a narrative lay in their grammatical choices of verbs. In the educational text, the students also found expressions such as "Dead plants and animals are attacked" and "the decomposers use," which introduce agency into the process they have to report. The use of a word such as "attacked" and the agency described in their account must, therefore, be seen in relation to the formulation of the educational text. However, what makes their report diverge from a scientific description of the mouldering process is not the active form as such, but more that the agency is attributed to other subjects than those intended.

Concluding remark

This study demonstrates, like other similar studies (e.g., Teasley and Roschelle 1998), that animated computer software has the potential to engage students in a joint problem-solving activity that results in shared meaning making of the visualised events. More interesting, however, is the fact that the results also point to the problem that students' interpretation of an animated scientific phenomenon is no guarantee of the intended learning outcome, even though prepared in a preceding lesson and accompanied by an educational text. The students in this study constructed a narrative describing the observed events and drew on resources from the following: characteristics of the animation as agency and temporality, the accompanying educational text where activity and intentionality were expressed, and their earlier experience and everyday language. Without sufficient background knowledge of the subject matter, the students' conclusion runs the risk of being deemed an incorrect description of the phenomena depicted. This analysis shows that an unguided construction of meanings from an animation runs the risk of leading to unintended and, hence, unscientific concepts. Joint meaning making of an animated scientific phenomenon does not automatically lead to the concept constructed by the learners being in accordance with what is intended. Thus, when designing and using educational software for school activities, in order to provide an understanding of scientific concepts, it is important to consider both cultural and semiotic processes.

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