Animations in Science Education

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ABSTRACT

The overall aim of this chapter is to explore some of the pedagogical potentials, as well as limitations, of animations displaying complex biochemical processes. As the first part of our larger research project, a learning environment was developed where visualisations by means of 3-D animations depicted some of the processes in the carbon cycle. In the analysis, we describe how three groups of students made use of and reasoned about the computer animations. In relation to the aim, three salient themes are discernible in the video material of the students' reasoning; the risk of focusing the attention on misleading aspects of the animation, the possible occurrence of a form of isolated reasoning, and the students' varying understandings of what resources they are expected to use when performing a given task.

INTRODUCTION

One of the grand themes of educational research in general and science education in particular is the notion of misconceptions. Students' misconceptions of various scientific principles are recurrent topics in numerous studies, for instance, in physics (Brown, 1992; Jones, 1991), biology (Brown, 1990; Odom, 1995), and chemistry (Goh, 1993; Nicoll, 2001; Sanger & Greenbowe, 1999). The means to meet the educational challenges spelled out by educators and educational researchers has obviously varied, but throughout the 20th century, the use of technological innovations has been an increasingly frequent strategy (Petraglia, 1998a, 1998b).

For higher biology and medical education, several digital applications have been developed.

Camp, Cameron, and Robb (1998) created virtual 3-D simulations enabling medical students to examine anatomic models, and Karr and Brady (2000) describe interactive 3-D technologies for teaching biology. Virtual learning environments for primary school (Mikropouls, Katsikis, Nikolou, & Tsakalis, 2003) and high school (Kameas, Mikropoulos, Katsikis, & Pintelas, 2000) have been developed and, in some respect, been tested out and evaluated.

Given all the time and effort invested in these matters, however, positive and stable results from the use of educational technologies are remarkably few. To underscore this observation, we would like to point to a claim by Euler and Müller (1999) who hold that, within the area of physics education, the technology known as *probeware* is the *only* computer-based learning environment that has a proven general positive learning effect. Adding to the picture that the area of physics education is intensely studied renders Euler and Müller's remark even more conspicuous. Thus, as a general pattern, students seem to be invariably immune to any simple technological treatments; despite whatever new technologies we introduce into our educational systems, *learning* continues to be a struggle for educators and students alike.

In spite of this rather gloomy outlook, ever-new items are added to the list of possible remedies of educational dilemmas and student difficulties. One item on this list and the topic of the current chapter is the use of *animations* as educational resources. Our specific field of investigation concerns secondary school science education, and the aim is to analyse the reasoning students perform when working with animated sequences of the carbon cycle.

THE CARBON CYCLE AS A TOPIC FOR EDUCATION

One of the main topics in curricula for primary and secondary schools for education of natural science is the carbon cycle and its vital importance for conditions concerning life on earth. Studies of the two main processes in the carbon cycle, *photosynthesis* (Barak, Sheva, & Gorodetsky, 1999; Cañal, 1999; Eisen & Stavy, 1993) and *respiration* (Sanders, 1993; Seymour & Longden, 1991; Songer & Mintzes, 1994) report that students' knowledge of these gaseous processes is poorly understood and that misconceptions are frequent. In consideration of the utilisation of fossil fuel and the ensuing global warming, combustion is another process in the carbon cycle deemed increasingly important. This process is chemically equal to the respiration with the exception that it is not a cellular process.

A major problem with the conceptualisation of the processes in the carbon cycle is that they involve gaseous forms that are not directly observable and therefore have to be grasped through some representational system. The traditional textbooks most often illustrate the carbon cycle in pictures furnished with arrows describing the course of the circulating material. Given an educational framing, one could conclude that there should be potential gains from developing educational material that builds on more dynamic forms of representations, for example, computer animations. From a research perspective, however, this still remains an open question. Before turning to the specific but still problematic question concerning the animation of the carbon cycle, we will briefly discuss recent work done on the use of different animations in education.

COMPUTER ANIMATIONS IN EDUCATION

The scientific results emanating from research exploring the educational value of animated graphics, as compared to the use of its static counterparts, are hitherto inconsistent. The research results so far display a complex and confusing array of outcomes in different educational settings. From an initial euphoria over the vast educational possibilities associated with multimedia technologies, a more composed picture is now emerging. However, the expectations of multimedia in educational settings, although somewhat moderated, still exist and they call for further research in the area.

Based on a series of studies, Mayer (1997) argues to have found consistent support for a generative theory of multimedia learning, and offers the explanation that coordinated presentation of explanatory words and pictures is effective because it helps guide students' cognitive processes. In addition, he demonstrates what he calls a contiguity effect when visual and verbal information is presented closely together. For the prospects of computer-based learning, he concludes: 'In computer-based multimedia learning environments students have the opportunity to work easily with both visual and verbal representations of complex systems, but in order to fruitfully develop these potential educational opportunities, research is needed in how people learn with multimedia' (p. 17). Most investigations comparing the learning outcomes of students' work with animated vs. static pictures, however, have not been able to show any enhanced learning efficacy brought by the animations. The results rather indicate the contrary. In a comprehensive research review, Tversky, Morrison, and Betrancourt (2002) could not find evidence supporting the view that animations are superior to the use of static graphics in education. Lowe (1999, 2003) suggests that merely providing an accurate animated depiction of the to-be-learned material may not in itself be sufficient to produce the desired outcome. In his studies of how meteorological novices worked with animated weather maps, the extraction of information appeared to be largely driven by perceptual characteristics of the display. Students unfamiliar with the depicted subject matter tended to extract information about components of the animation with characteristics such as structural coherence, distinctive appearance, and dynamic change more readily than they extracted information about components lacking these qualities. Retention also seemed more likely for those aspects of the dynamic graphics that were relatively easy to extract. This extraction and retention of the most perceptual salient characteristics of animations, irrespective of their relevance with regard to the intended subject matter, is something one has to take into account when designing educational animations. Lowe (2003) also concludes that the problem appeared to stem from lack of explicit information about the relative importance of various aspects of the animation, and he conjectures that students could be helped by providing the learning environment with specific visual and temporal guidance. Consequently, he proposes that further research is needed to determine if these findings can be generalised and how the animations might be manipulated in order to modulate the way in which students' attention is distributed between features that differ in their intrinsic perceptibility.

Mayer, Hegarty, Mayer, and Campbell (2005) made four experiments comparing the learning outcomes of the use of computer-based animations and narration versus paper-based static diagrams and text. Based on these experiments, the authors argue that static presentations containing illustrations and printed text can be superior to dynamic presentations containing narrated animation. Their reasoning is further given a theoretical framing, from within which static media is seen as having the advantage of engaging people in less extraneous cognitive processing. By that line of reasoning, one is therefore able to engage in deeper cognitive processing when learning from static illustrations and text, as compared to dynamic animations and commentaries. On the other hand, Mayer et al. (2005) remark that their study should not be interpreted as if animations are ineffective in all situations. For example, animations are said to improve understanding for learners with limitations in spatial ability or when they are used to visualise processes that are not visible in the real world.

When comparing individual and collaborative learning with interactive animated pictures vs. static ones, Schnotz, Böckheler, and Grzondziel (1999) found that animated pictures could result in better learning about dynamic subjects for individual learners but lead to lower learning results in collaborative learning. They attribute their results to the effect that collaborative learners have to devote a substantial proportion of their cognitive processing capacity to both operating the visual presentation and coordinating their learning activity with those of their partner. In accordance with this view, learners working collaboratively would have less cognitive resources available for processing the learning content. However, conflicting results are presented by Rebetez, Sangin, Bétrancourt, and Dillenbourg (2005) who demonstrate a positive effect of animated graphics over static ones for students learning in pairs compared to individual learners. These authors interpret their results by the *underwhelming effect* described by Lowe (2003): participants working on their own were less active because they simply had to attend to the animation and not to build a shared representation of the animation with a partner leading to the illusion of comprehension. In summary, both the referred studies explored computer animations and compared students working individually to students working in pairs, but they come to contradicting conclusions. One possible explanation is that the learning conditions were quite different in the two studies. For example, Schnotz et al. (1999) used interactive animated pictures while the participants in the study by Rebetez et al. (2005) had no control over the presentation. In relation to this, we hold that there is a need to consider the educational setting, in which animations are used for understanding the learning outcome.

Under the auspices of cognitive load theory, another factor thought influencing the learning outcome when using animations is the students' learning prerequisites. Animated pictures are regarded as having a facilitating function insofar as they allow an external simulation process that makes an alleged corresponding mental simulation less demanding (Schnotz & Rasch, 2005). Accordingly, this is seen as beneficial for learners who would not be able to perform this operation without external support but, on the other hand, as harmful to learners who could perform the mental simulation on their own. In the latter case, the authors argue that the animation reduces the cognitive load but also reduces germane load that is necessary for learning. Schnotz and Rasch conclude that, 'The use of animation in multimedia learning environments seems to be beneficial only under some circumstances, whereas it can have negative effects under other circumstances' (p. 57).

What advantages can an interactive computer animation entail in comparison with, for example, viewing a film illustrating the same process? By breaking down an animated presentation into short segments, Mayer (2001) showed that students who were able to control the presentation pace—by clicking on a button to receive each of the segments—performed better on transfer tests than did students who viewed the entire presentation as a continuous unit. Thus, it seems as if this form of interactivity can help overcome some of the difficulties of perception and comprehension associated with animations. As argued by Tversky et al. (2002), simply enabling the starting, stopping, and replaying of an animation will allow for re-inspection and facilitates the user to focus on specific parts and events.

The interest for computer games is considerable among the youth today, and many students are therefore familiar with virtual environments of this kind. Among educators, there have been recurring attempts to buy one's way into the success of the gaming industry by adopting part of its format. One example is the Viten project which has its roots in WISE (developed by the WISE-project at the University of California, Berkeley and available at http://wise.berkeley.edu). Like WISE, the Viten project is free and open software (available at http://viten.no), enabling science teachers to use Web-based science curriculum materials. It presents programs combining text, simulations, and animations in topics of science and mathematics. In the most popular Viten program, Radioactivity, the interactive animations and other features are described to contribute to student learning by making the 'invisible' visible (Mork, 2005). When summarising students' positive comments, Mork (2005) identifies a number of categories which are thought to provide some general insights about what is appreciated in a teaching sequence, that is: using computers, variation, informative materials, working together, and student control. On the one hand, these are key words to have in mind when planning any teaching sequence or when developing new learning materials. On the other hand, they are also very general descriptions, too abstract in order to provide any substantial insights, and every such term must therefore be disambiguated and given a specific content on every new occasion and in every new educational design (Lindwall & Ivarsson, 2004, in press).

AIM OF THE STUDY

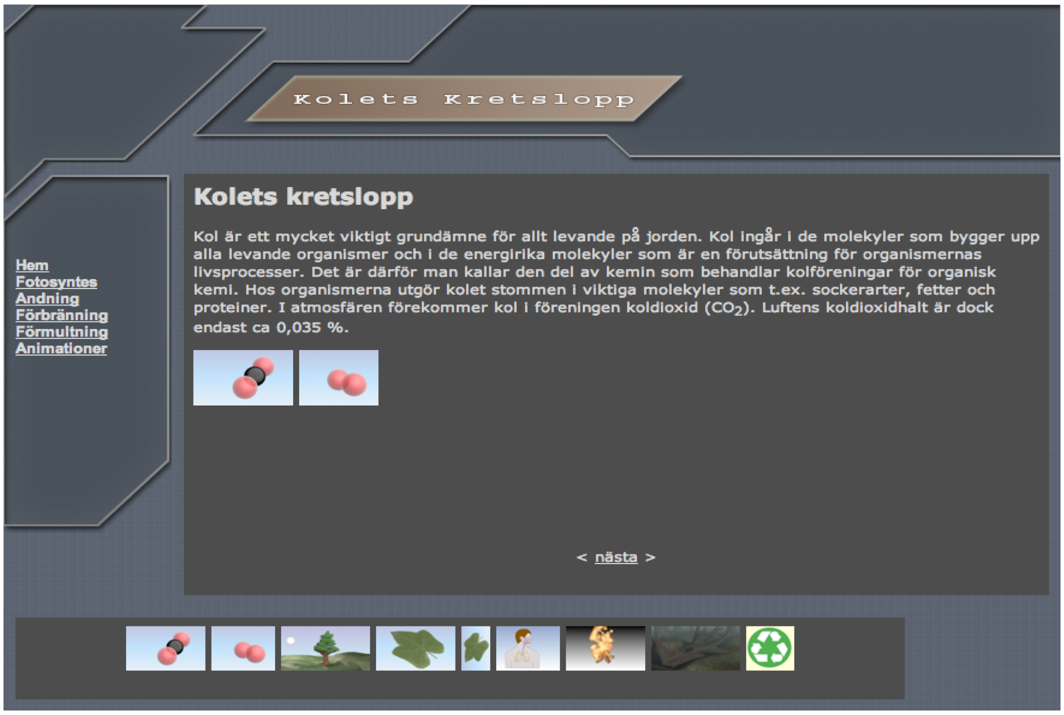
So far, studies of the educational use of animations have mainly been concentrating on the learning outcomes in quantitative terms. In this study, we analyse the reasoning and interaction taking place when groups of students collaborate in connection to a set of animations. Interaction analyses of knowledge building in small groups is an emerging and important methodology in the area of computer supported collaborative learning (CSCL) (Stahl, 2006). Arguably, the better we understand the students' collaborative reasoning on a given topic, the better we can design specialist computer support and the surrounding learning environment in which this support is intended to serve. Evaluating new educational setups also raises the problem of how technology interacts with the students' emerging conceptualisations. By analysing the students' interaction and talk, we aspire to gain insights into their interpretations of the depicted phenomena. The overall aim of this study is to explore some of the pedagogical potentials, as well as limitations, of animations displaying complex biochemical processes. As the first part of our larger research project, a learning environment was developed where visualisations by means of animations depicted some of the processes in the carbon cycle.

APPLICATION DESIGN

The background and motive of developing a sequence of computer animations can be found in the educational situation of the specific subject matter: the carbon cycle. As already alluded to, the teaching of this topic could, as seen from the science teacher point of view, potentially benefit from having an educational material that builds on dynamic forms of representations.

The intention in forming the design was to make the illustrations in the graphics as concrete as possible and to concentrate on just one event in every sequence. Software for the production of 3-D animations was used for the development of the pedagogical application (available at http://www.ituniv.se/~gorkar/). The index page in Figure 1 contains a text describing the main outlines of the carbon atom cycle. To the left, there is a menu with links to the different pages in the application. At the bottom, there is a row of clickable miniatures that links to the different animations. The pages describe the different processes of photosynthesis, breathing, combustion, and mouldering. Each page has an explanatory text which was kept as concise as possible so as not to be considered too tiresome to be read by the students. Underneath the captions, there is a miniature image linking to the animations. The program allows for some limited interactivity as the students can start and stop the animated sequences.

Figure 1. The index page from where you navigate among the animations of the processes in the carbon atom cycle



Photosynthesis is illustrated in three animated sequences. The three sequences in various ways illustrate carbon dioxide molecules diffusing into the leaves of a tree, the building up of the foliage, and oxygen molecules emitting from the leaves. *Breathing* is illustrated by the human lungs in section. The animation shows how oxygen, which is taken in through the respiratory passages, is exchanged for carbon dioxide that is exhaled. Since the breathing is an active process, the animation gives a reasonably correct picture of the actual process. However, the cellular respiratory process and gas transportation with the blood are not shown in the animation. Furthermore, the animation displays the inhalation air by means of only oxygen molecules, and similarly, only the carbon dioxides are represented in the exhalation air. In reality, there is a mix of gases in both the inhalation and exhalation air where oxygen and carbon dioxide constitute a minor part and where only the proportion of these gases differs. Thus, the animation constitutes a considerable simplification of the real events.

Mouldering and *combustion* are illustrated by a mouldering log and a log fire, respectively. The wood is used for making the connection easier between the photosynthesising tree and the mouldering or burning tree. In the animation of both mouldering and combustion, one will see oxygen molecules coming in from the side and carbon dioxide molecules leaving the log and the log fire respectively in an upward direction. Again, this is a simplified and schematic illustration of indiscernible and passive gas exchanges, and it does not show the actual processes occurring inside the wood.

In conclusion, common to all animations is that they focus on the movements of the gaseous molecules oxygen (O_2) and carbon dioxide (CO_2) in the different depicted processes. It should be noted that, as the animations are designed to emphasise these relations, this form of highlighting (Goodwin, 1994) simultaneously runs the risk of concealing other important molecular reactions. The relation between possible advantages and drawbacks connected to the use of this form of representation constitutes a major part of the empirical study, and it is this issue that we will address in the analysis.

RESEARCH DESIGN

A total of 40 students attending a science course in a Swedish secondary school took part in the study. The 16 girls and 24 boys were grouped into dyads or triads, totalling 19 groups, thus allowing peer discussions and engaging the students in reflection and comparing their different views with each other. The study was conducted during a one and a half hour study session for each group.

Before starting their exploration of the animations, the students were given a short instruction about how to manage and navigate within the learning environment. There was no tutorial introduction of the topic, but the students had the opportunity to consult their teacher during the learning session. The students also got an explanation of what a model of a phenomenon means. It was stressed that when using simulations as models for real phenomena, the students must not mistake a simulation for the actual phenomena (cf. Flick & Bell, 2000). For about 20 minutes, the students worked with the animations. During this time, they were given the task of writing down what they saw happening in the different sequences. After that, while still having access to the animations, they were assigned to discuss and jointly give answers to two problems concerning the carbon cycle.

To gain an understanding of how the students interpreted their tasks and reasoned about the animations, three groups were randomly selected and videotaped during the entire session. The analysis builds on the work of these three groups. This analysis of the students' interaction with each other and with the technology draws on an analytic tradition which Jordan and Henderson (1995) summarise under the label *interaction analysis*. Like the authors, we find this interdisciplinary method for the empirical investigation of human activity particularly helpful in complex, multi-actor, technology-mediated work settings and learning environments. Through the detailed analysis of videotaped material, this method tries to describe the ways participants orchestrate both communicative and material resources when performing any given task (Ivarsson, 2004).

RESULTS

In relation to the aim of understanding the pedagogical workings of the specific animations displaying complex biochemical processes, three salient themes are discernible in the video material of the students reasoning. The first concerns the risk of focusing the attention on misleading aspects of the animation, a problem in some respect related to the design of the technology. A second problem observed is the possible occurrence of a form of isolated reasoning, seemingly connected to the simplified nature of the representations. The last observed problem is the students' varying understanding of what resources they are expected to use when performing a given task.

Misguided Attention

As the animations are mere models of unobservable molecular processes, the interpretations of these representations can result in several misleading inferences. One example of such a misleading feature of the animation, not really belonging to the model, is observable in an excerpt where three students are watching the animation of gaseous exchange by a photosynthesising tree.

Veronica:	now you see what is happening, what happens
Henric:	ok, carbon dioxide molecule gets stuck, in the tree
Veronica:	in the tree and oxygen, oxygen
Henric:	oxygen carb-eh-molecule
Veronica	came out
Henric	blows away

Veronica is asking Henric what happens in the animation. Henric explains what he observes with a mix between scientific designations and every day expressions like ‘gets stuck, in the tree’ and ‘blows away.’ These specific wordings are later adopted by Veronica, as shown in the next excerpt.

Veronica:	there we shall write the first picture shows that oxy carbon dioxide or what- ever it’s called gets stuck in the tree and oxy blah-blah, blows away as he said
Henric:	ok, the tree catches oxygen molecules through blowing or something like that it stays so the oxygen keeps on blowing

Veronica remarks that carbon dioxide ‘gets stuck’ and oxygen ‘blows away,’ thereby referring to Henric’s earlier utterance. Henric makes no distinction between the two kinds of molecules and does not comment on the assimilation of carbon dioxide. His remark about ‘blowing or something like that’ could indicate an uncertainty about the blowing as the driving force for the molecules. However, when subsequently asked by the teacher what is shown in the animation, he reiterates and reinforces the narrative about the ‘blowing’ that makes ‘the tree catches oxygen molecules.’

Teacher:	yes what is happening here?
Henric:	yes we only saw oxygen molecules and by means of blowing it gets stuck
Veronica:	((*clicks at the icon showing the photo synthesis*)) look there- what’s coming
Teacher:	yes look what’s coming here, what is it that gets stuck

Henric responds to the teacher’s question by focusing on the perceptual salient feature of the oxygen molecules as moving in one direction. In his words, this ‘blowing’ is the cause that makes the molecules ‘get stuck’ in the leaf. Veronica refers to the carbon dioxide molecules as something that is ‘coming.’ This particular way of talking about the depicted processes is not corrected by the teacher, not in this excerpt nor in the subsequent discussion with the group. Instead the teacher repeats the somewhat misleading characteristics of molecules as ‘coming’ and ‘getting stuck’ and tries to focus the student’s attention on the actual molecules.

Isolated Reasoning

The animations show only limited parts of the complex biochemical processes occurring inside organic material. This is an inevitable feature of any model. But, the interesting question is whether the limit of scope functions differently with an animation as compared to a static picture. The observations in the next two excerpts do indicate something in that direction.

Said:	((*reads from the questionnaire*)) the following questions you can discuss with a peer and write down which conclusion you have reached, one- we breathe in oxygen and breathe out carbon dioxide, from where do the carbon atoms in the carbon dioxide that we breathe out come from (3 s) uhm yeah we breathe in oxygen and like from where do the carbon atoms in carbon dioxide that we breath out come from

Kevin: yeah that's you know from pollution

Said: carb- carb- the carbon atoms

Kevin: isn't it from pollution from the car and things

Said: no I don't know

Kevin: 'cause we don't breathe in 100% oxygen

Said: then from where come the carbon atoms in the carbon dioxide that we breathe out hmm (6 s) yea then isn't it so that when we breathe in then we like take when we breathe out then it becomes carbon dioxide it means that (2 s) it has to come from our lungs then

Kevin: yes

Said: where they sort of are cleaned or some cycle in our lungs like

Kevin: from where do they come, are they from, we don't breathe in 100 % oxygen do you understand what I mean?

Said: yes ((*watching the animation showing breathing*))

Kevin: then (2 s) they probably come from (3 s) exhaust pipes from cars and such

Said: I think so too

The animated sequence that the students have recently watched is making visible the processes of inhalation and exhalation and thereby focuses on the two different gases (oxygen and carbon dioxide). Similarly, the dialogue between the two boys takes its starting point from the assumption that the carbon atoms originate from an airborne external source and reach our lungs through the inhalation air. In their discussion, they stick to this rationale and endeavour to conceive of a source emitting carbon atoms into the air. As we can observe, their discussion is completely concentrated on a circulation of the carbon atoms inside the lungs. In one sense, this is an adequate way of reasoning, since the animation of the breathing is only visualising the gas exchange in the lungs. Presumably, they did not read the caption explaining the metabolism, thereby restricting the external input of their reasoning to the limited view that was given by the animation. The reading of the text was not expressed in their task, and this group did follow the instruction, which was to discuss with a peer what they could observe and thereafter write down their conclusion. In this case, this obviously led them to an erroneous conclusion, which could possibly have been avoided if they had been encouraged to read the text captioning the breathing animation.

Another example of this somewhat isolated reasoning, and misleading inferences due to limitations of the animation, is demonstrated in the excerpt. Here, two girls are watching and discussing what happens in the animation illustrating the combustion by a burning log fire.

Gloria: oxygen comes in

Petra: and out,

Gloria: comes carbon dioxide

Petra: so oxygen is necessary for the fire to burn and out then just like in the human body when the oxygen is consumed carbon dioxide comes out

Gloria: carbon dioxide comes out

Petra: does that sound probable?

Gloria: that sounds very sensible in some way

Petra: you know from you were playing with candles when you were little when you put a glass over it takes a while before it goes out

Gloria: yeah
(7 s)

Petra: but to make something burn you have to have some material that can burn

Petra: but that's what you- that would be the oxygen then

Gloria: yes. in principle

In the beginning of this discussion, Petra displays a very knowledgeable reasoning about the requirement for oxygen in the combustion, referring to the experience of putting a glass over a candle. She then remarks on the necessity of having some burning material. Gloria suggests that this would be oxygen, whereupon Petra agrees with her. Coming to the erroneous conclusion that oxygen is the burning material can be a quite understandable consequence if only watching the animation. Here the oxygen molecules can be seen moving into the log fire and the carbon dioxide molecules leaving, whereas the firewood remains unaltered. Consequently, the animation offers no way of discerning the chemical process actually taking place during combustion.

The animations, as mentioned, focus on specific relations in the biochemical processes, and they thereby necessarily downplay, or hide, other potentially relevant aspects. Here we have two examples where this seems to become a pedagogical problem. The fact that something very specific is highlighted by the animation could also imply that one has a harder time breaking out of that offered frame. In this way, the learning environment invites to way of reasoning that, at times, becomes isolated in relation to the overall topic (for a similar discussion, see Ivarsson, 2003).

Conflicting Perspectives

The students' first task was to describe what they could observe in the animations. When analysing the reasoning of the students, this seemingly easy instruction opens into a complex task that holds two conflicting perspectives. In the excerpt, Petra and Gloria are discussing the animation of breathing.

	((*Petra clicks on Breathing in the menu and both girls read the text about breathing,* 29 sec))
Petra:	are we ready?
Gloria:	Yeah
Petra:	Oxygen
Gloria:	oxygen you breathe in so you breathe out carbon dioxide
Petra:	carbon dioxide they transform there
Gloria:	they transform in the lungs
Petra:	it must be
Petra:	yes
	((*Petra makes notes,* 28 sec))
Gloria:	but really it's not like that, that they come in and become carbon dioxide when you breathe out but it's about oxygen coming in, and going out into the cells
Petra:	Ah
Gloria:	and then they take it up
Petra:	but what you see in the animation
Gloria:	in the animation it is that then you see that oxygen comes into the lungs and carbon dioxide comes out
Petra:	(*reads aloud the text from the questionnaire*) it says explain in your own words what you consid- what you see happening in the different animations
Gloria:	all right then it's what you see sort of ((*make notes,* 9 sec))
Petra:	I wrote used up slash transforms

Here two conflicting perspectives become apparent. This is about how to explain the breathing process both described in the caption and visualised in the animation. The two girls at first conclude that there is a transformation in the lungs, but then Gloria points out that it actually is a more complex process involving the gas exchange occurring inside the cells. Petra, on the other hand, refers to the written task where they explicitly have to explain what they 'see happening' in the animation. Gloria admits that it is what they can observe that they have to report in their notes.

These conflicting perspectives between the task (as referred to by the students) and the visualisations are also visible in the excerpt from the triad group. Here Martina, sounding somewhat annoyed over her companions reading of the text, stresses that they have to write down what they 'see.' Later on in this group's discussion, the same tension arises over what their assignment really is about.

Henric:	are we going to explain what photosynthesis is?
Martina:	we have to write down what we see
Veronica:	photosynthesis

Henric:	yea wait there it says ((*reads the text about the photosynthesis on the screen*)) the plants absorb
Martina:	<u>in your own words or</u>
Henric:	what do we have to write down (.) what's happening?
Martina:	<u>yea that's it</u>

Henric shows that he is in a quandary over what their assignment is about. Martina emphasises three times the explicit wordings in the questionnaire, specifically what their task is about. When Henric is trying to read the text accompanying the animation, Martina interrupts him and stresses that it should be 'in your own words.' For Martina, reading the text obviously implies that they will not be able to describe what they see with their own words. Thus, she clearly regards the use of what is mentioned in the captions to be in conflict with their task.

DISCUSSION

The analysis shows how students watching the animations use expressions from their every day life to talk about what is displayed on the screen. As they, in their capacity of being students, lack knowledge of the subject matter, they have to impose an interpretation of their own, and they do this by drawing on a variety of resources. In their efforts to make the events in the animation meaningful, the students incorporate every day language in their descriptions of the depicted processes. At times, this leads them to make unintended interpretations of the scientific model. However, such use of every day language and even bodily experiences when attempting to grasp abstract phenomena, is not solely done by students, but also by professional scientists in their ordinary work (Ochs, Gonzales, & Jacoby, 1996). Consequently, we regard this as a pedagogical problem of a more general nature, and not specifically tied to the use of animations.

The earlier documented problem, that students tend to focus on perceptually salient features of the animation, could also be observed in our material. In relation to these features, Lowe (2003) found a predisposition by novices to impose simple every day cause–effect relations on the interpretations of the animations. Examples of this kind, in the excerpts, are the interpretations of molecules as 'blowing' into and away from the tree and oxygen being 'consumed.' The analyses also show how easily such inferred notions are accepted and taken up by the coparticipants and, more problematically in our case, even by the teacher. So, what kind of guidance would be necessary to overcome this problem then? An instructional text accompanying the animation could be one way of redeeming these issues, but this method offers no guarantee that the text will actually be attended to. Another suggested way of supporting animations has been narration coordinated with the animation (Mayer, 1997). Although Mayer et al. (2005) found no support for the superiority of computer based narrated animations over paper based annotated illustrations, they conclude that their study 'should not be taken to controvert the value of animation as an instructional aid to learning. Instead, this research suggests that when computer-based animations are used in instruction, learners may need some assistance in how to process these animations' (p. 246). Obviously, teacher supervision could also provide students with the guidance needed for construing animations in an adequate way. This, however, being the panacea to all educational dilemmas adds nothing new to our further understanding of the use of animations for specific learning purposes.

Another theme, worthy of further scrutiny and briefly touched upon in the analysis is the topically isolated reasoning that can be observed in connection to the animations' superficial depiction of the biochemical processes. In biological terms, respiration takes place inside the cells and the gases are transported to and from the lungs with the blood. In the animation of breathing, however, the gaseous exchange was only illustrated within the lungs, showing oxygen being inhaled and carbon dioxide leaving the lungs. This delimitation of the illustration in some cases leads to erroneous inferences like carbon dioxide being formed in the lungs or originating from an outside airborne source. In the students' effort to answer the question about the origin of carbon atoms in the exhalation air, they had to turn to resources external to the actual animation. To make the judgement of when to go outside the provided material and when to stick with it is not a trivial task, however. By using the written information in the caption, most students were able to get the correct information. But without this source, they were restricted to either their previous knowledge or to observing the animations. Given this latter scenario, a conclusion such as 'carbon dioxide reaching the lungs from an external source' is fully understandable.

In addition, we would like to comment on the distinctive situation of solving educational problems. As a general observation, students are often oriented towards the short-term goal of fulfilling a given task by the production of an answer to a specific question. When solving such a task, the students can use varying resources like earlier experiences, texts, instructional graphics, and so on. Here, the conflict over *what* kind of resources they are expected to use, and *how* to use them, can be discerned in the students' argumentation. It is in this process that an explicit formulation of how to perform a given task can be interpreted as excluding other forms of resources. The formulation in the current assignment, 'explain in your own words what you can *see* happening in the different animations,' did in this case lead some students to the conclusion that they, in their written answer, had to disregard their previous knowledge or what they could read in the text captioning the animations. Even though the intention with the question was to make the students draw their own conclusions from the animation and not only copy the text, this formulation in fact created an increased uncertainty of how to proceed. Considering this, it seems very important to pay great attention to the formulation of the assignments that students are going to perform in their work with animations.

FINAL REMARKS

Any graphical illustration of the complex biochemical processes involved in the carbon cycle will entail simplifications of the real courses of events. As suggested by the observations, perhaps animations, more so than static images, could help create the illusion that a complete process is being illustrated. Regardless of how sophisticated the animation becomes, there will always be grounds for misinterpretations. Prescribed ways of overcoming these drawbacks have been through increased interactivity (Tversky et al., 2002) or activities that generate explanations or answering questions during learning (Mayer et al., 2005). Other ways could be through instructional guidance, either written or narrative. When text and animation are simultaneously presented, the observers' visual attention has to be split between the animation and the text. In our study, the image *presenting* the animation was captioned, but as the sequence was started, the text disappeared. Hence, the students had to change between two pages when they wanted access to the written information vs. the animations, something that should be reconsidered given a future redesign. Still, an important issue for the observed students was which of these two media, the animation or the text, were of superior significance when fulfilling their task. Here the formulations of their task sometimes led to the exclusion of the written information and even of their previous understanding of the subject matter at hand. To make the students integrate visual and verbal information, the task has to be formulated in a way that supports the utilisation of all available resources.

Finally, the observations of our study merely point out a field of investigation that needs further attention. In our view, animations provide an interesting educational offering, with some pedagogical potential. They do not, however, come without costs. What is suggested by our observations is that in a worst case scenario, the animation will operate as a counteracting force that, instead of supporting knowledge building and working against faulty interpretations, will do the exact opposite and take the role of an antagonist of conceptual development.

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KEY TERMS

Computer Animation: The art of creating moving images via the use of computers.

Computer Supported Collaborative Learning (CSCL): Research area in supporting collaborative learning with assistance of computer artifacts.

Conceptualization: Creating an idea or explanation and formulating it mentally.

Interactive: Refers to computer software which responds to input from humans.

Misconception: A false conception or abstract idea that is held by a person.

Simulation: An imitation of some real process.

Visualization: A technique for creating images or animations to communicate a message.

Handbook of Research on Digital Information Technologies:
Innovations, Methods, and Ethical Issues

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