Animated science education: Possible pitfalls of computer supported collaborative learning

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Misconceptions – This notion is one of the grand themes of educational research in general and science education in particular. Students' misconceptions of various scientific principles are recurrent topics in numerous studies, in for instance physics (D. E. Brown, 1992; Jones, 1991), biology (C. R. 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 twentieth century, the use of technological innovations has been an increasingly frequent strategy (Petraglia, 1998a, 1998b).

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 the remark by Euler and Müller 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 study, is the use of *animations* as educational resources. Our specific field of investigation concerns secondary school science education and the aim is to analyze 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. A major problem with the conceptualization of the processes in the carbon cycle is that they involve gaseous forms that are not directly observable and therefore have to be grasped trough some representational system. Textbooks most often illustrate the carbon cycle in pictures furnished with arrows describing the course of the circulating material. Given this educational framing, one can conclude that there should be potential gains from developing educational material which build on more dynamic forms of representations, e.g. computer animations. From a research perspective, however, this still remains an open question.

Aim of the study

So far, studies of animations for educational use have mainly been concentrating on the learning outcomes in quantitative terms. In this study, we attempt to study the interplay and interaction taking place when the groups of students collaborate in connection with the animated phenomenon. 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' reasoning in collaborative settings about a presented phenomenon the better we can design computer support and the learning environment in which this support is intended to serve. Evaluating a new educational technology also raises the problem of how the technology influences students' conceptualization about the observed phenomenon. By analyzing the students' interaction, we aspire to gain insights into their interpretations of the depicted phenomenon. The overall aim of this study is to explore some of the pedagogical potentials, as well as limitations, of animations displaying complex biochemical processes.

Study design and implementation

As a first part of our larger research project, a pedagogical application (available at: http://www.ituniv.se/~gorkar/) was developed where visualizations by means of 3-D animations depicted some of the processes in the carbon cycle. The index page contains a text describing the main outlines of the carbon atom cycle. At the bottom is a row of clickable miniatures linking to the different animations and to the left a menu with links to the pages in the application. The pages describe the different processes of; photosynthesis, breathing, combustion and moldering. Each page has an explanatory text and underneath the captions there is a miniature image linking to the animations.

A total of 40 students attending a science course in a Swedish secondary school were chosen for the study. The students were grouped into dyads or triads, totaling 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 1.5-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 the teacher during the learning session. 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 animations. After that, while still having access to the computer animation, they were requested to discuss and jointly give answers to two problems concerning the carbon cycle.

To get a richer picture of how the students interpreted their tasks and reasoned about the animations, three groups were videotaped during their co-operative work. The analyses build on the videotaped interactions and focus on how the students made use of and reasoned about the developed computer animations. The analysis of the students' interaction with each other and with the technology draws on extensive work concerning interaction analysis (Jordan & Henderson, 1995).

Results

Three salient themes are discernible in the video material of the students reasoning in connection with observing the animations and solving the given tasks. These three themes all point to problematic issues that need more attention and further scrutiny in relation to the development of specific educational materials based on animations. Our ambition with this study has merely been to identify some relevant aspects that should and will be addressed more in detail in our upcoming work.

The first issue concerns the risk of misrepresentations and focusing the attention on misleading aspects of the animation which is a problem in some respect related to the design of the technology. As the animations are mere models of unobservable molecular processes, the interpretations of these representations can result in several misleading inferences. In the material such misleading models could be discerned when some students drew undesired conclusions about the driving force behind the gaseous exchange occurring in organisms and organic material. Examples were interpretations of molecules 'blowing' into and away from a leaf and oxygen 'coming' into a fire or a dead tree and being 'consumed'. In order to depict the gaseous exchange in photosynthesis and combustion the molecules were illustrated as moving objects. For example carbon dioxide molecules are seen moving into a leaf and oxygen molecules are leaving the leaf. Providing molecules with locomotion can seem an inevitable consequence of visually illustrating an otherwise passive gaseous exchange but can lead the observer to assume such a salient feature for the actual fact.

A second observed problem was the students' different understandings of what resources they were going to use when performing a given task. In the initial task the students were working with, they were instructed to "describe what they could observe in the animations". Depending on this formulation of the assignment, there sometimes arose conflicts between previous knowledge of the subject matter at hand and what were visible and observable in the animation. An example of this conflict became visible in a discussion between two girls when dealing with the animation of breathing. The two girls at first conclude that there occurs a transformation in the lungs but then one of the girls pointed out that it actually is a more complex process involving the gas exchange occurring inside the cells. The other girl then referred to the written task where they have to explain what they see happens, in the animation. They then concluded that it is what they could *observe* that they had to report in their notes.

The last problem observed in the study could be described as a form of isolated reasoning, partly originating from the animations. As the animations show only limited parts of the complex biochemical processes occurring inside organic material, this can be a cause of delimited and somewhat erroneous reasoning, perhaps even leading to false impressions about what the animation attempts to achieve. One of the tasks performed by the students was to give an answer to the question about the origin of the carbon in the exhalation air. Most groups gave the scientifically acceptable answer that the carbon originated from the food. In one, deviant, however interesting case, the answer provided was that carbon in the exhalation air originates from exhaust emissions. When looking at the dialogue between these two boys, it became apparent that they took as their starting point the assumption that carbon atoms originates from an airborne external source and reaches our lungs trough the inhalation air. In their discussion they therefore endeavored to conceive of a source emitting carbon atoms into the air. In summary, their discussion was completely focused on the circulation of gas the in the lungs where the carbon atom never reaches the tissue cells. In one important sense, this should be seen as an adequate and fully rational way of reasoning, given that the animation of the breathing was only visualizing the gaseous exchange in the lungs. One interesting, however not studied, reflection in relation to this observation is whether the animation, in comparison to static images, more often are treated as "more complete"? From our ubiquitous acquaintance with images we know that they render occurrences that are stretched out in time rather poorly. With animations however, it could be the case that the borders between what is represented and what has been omitted are less clear.

The exploratory character of the study makes it impossible to answer the question about the commonality of these occurrences. Taken together, these observations point out a field of investigation that needs further attention. In the worst case scenario, the animation will operate as a counteracting force that – instead of supporting knowledge building and working against the formation of possible misconceptions – will do the exact opposite; it may take the role of an antagonist of conceptual development.

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