Joint Reasoning about Gas Solubility in Water in Modified Versions of a Virtual Laboratory

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Abstract: A virtual laboratory was designed to enable students to collaboratively discover the concept of gas solubility in water at different physiological conditions. The virtual laboratory was developed through a design experiment involving three successive versions with different guiding structures. Analysis of 13 dyads' reasoning about gas solubility in water revealed that the students' problem was to understand the concept of solubility of gases. It was also observed how the guiding structures within the three different versions influenced the students' reasoning about the concept.

Virtual laboratories – digital, simulated laboratory experiments, debated and subject to methodical research – have been used for decades. It has been proposed that virtual laboratory work could have the potential to alleviate many of the problems connected with traditional hands-on experiments (Ma & Nickerson, 2006).

Within a joint development and research venture we developed a virtual laboratory (available at http://esi.stanford.edu/gasesinwater/gasesinwater1.htm). It was carried out through an iterative design experiment that included three loops of slightly altered versions of the virtual laboratory. To guide students in their collaborative discovery process, the virtual laboratory was facilitated with several scaffolds (Gijlers, Saab, & Van Joolingen, 2009; Vreman-de Olde & de Jong, 2006). A collaborative learning setting has been shown to benefit learning from animated graphics about natural dynamic phenomena (Rebetez, Bétrancourt, Sangin, & Dillenbourg, 2010). Especially in the area of computer-supported collaborative learning (CSCL), analyses of knowledge building in small groups have developed into an important methodology (Stahl, 2006).

This paper presents findings from the reasoning of 13 student pairs as they explore the solubility of gas in water at different temperatures and water salinities in a set of virtual laboratory experiments. The purpose of the study is to add to the understanding of students' collaborative construals of the concept of gas solubility in water in modified virtual laboratory environments with different guiding structures.

Methods

In the development of the virtual laboratory, a formative iterative process was followed where the design was revised and modified in three repeated cycles. Each version contained additional built-in guidance such as introduction films, gas meter, folding menu, educational texts and pop-up boxes suggesting alternative actions. Changes of guiding structures within the virtual laboratory were based on observations, questionnaires, and interviews with teachers and students from the previous evaluation.

When performing the laboratory experiment, the students were assigned to work in pairs. From observations of the efflux of bubbles when the water is heated and shaken and when salt is added, the students were expected to draw conclusions about the dissolution of the two gases oxygen and carbon dioxide in water at different conditions. The desired learning outcome is primarily that they shall acquire the insight that higher temperature or salinity decreases gas solubility in water.

The virtual laboratory was evaluated in the spring of 2008 at four upper-secondary schools in the area of Gothenburg, Sweden and involved eight classes, totaling 180 students ages 16-19. The evaluation process included interviews, discussions with focus groups and video recordings. In order to investigate the nature of the students' reasoning, the video recordings of 13 groups discussing the virtual laboratory experiments were transcribed and analyzed. Five groups worked with the first version, four each with the second and third version of the virtual laboratory. The filmed groups were randomly selected from the four schools; they studied the same program and were assumed to be of similar abilities.

Results

In the virtual laboratory, a burst of bubbles is seen when the water is either heated or salted, indicating that less gas remains in the water. The results from the evaluation process indicated that the problem was not primarily for students to realize that warmer water contains a decreased volume of gas, but rather to understand the concept of solubility of gases in water in relation to bubbles emerging from the water. The analysis of the video data corroborated this observation but also expose dissimilarities in the students' reasoning in relation to which version of the virtual laboratory they were exploring.

Among the five groups that worked with the first version, four discovered that an increased amount of bubbles means a decreased volume of gas in water, whereas one group held an erroneous view. In terms of the concept of gas solubility in water, all five groups held the erroneous view that more bubbles leaving the water implies that more gas dissolves. It is noteworthy that the four groups that reached the insight that an increased amount of bubbles means a decreased volume of gas in water nevertheless did not discover the scientific concept of gas solubility in water. Of the four groups that worked with the second version, all made the observation that more bubbles imply a decreased volume of gas in water. All groups also reached the intended learning outcome that more bubbles imply that less gas is dissolved. It can be observed that in three groups, one of the interlocutors initially held an erroneous view, but subsequently after discussing with his/her partner became convinced about the scientific concept. The four groups that worked with the third version noticeably differ from the other nine groups in their reasoning. In these groups the students were just reading off the gas meter and declared that the volume of gas decreases when the water is heated and there was no further discussion about the concept of gas solubility in water.

Discussion

The main purpose with the design of the virtual laboratory was to provide students with resources to discover the relation between gas solubility in water and temperature. Analyses of the filmed groups reasoning disclose that the problem might not be so much that the students did not grasp that the volume of gas in water decreases when the temperature rises, but instead that they did not understand the link between the concept of solubility of a gas in water and bubbling.

Compared to traditional laboratory work, the virtual laboratory provided extra affordances in terms of guiding structures. For example, in the second version of the virtual laboratory, a film showing molecular reactions inside the soda bottle and an assignment box with educational questions was introduced. The results show that while all four groups that worked with the second version discovered the scientific concept, no one of the five group that worked with the first version did. In the four groups that worked with the third version, there were no discussions of the meaning of more bubbles in terms of the concept of gas solubility in water, whereas such discussions were frequent in the groups with the first two versions. A plausible explanation for this might be found in the fact that these four groups explored a version of the virtual laboratory that was complemented with a gas meter. It can be assumed that the gas meter, displaying the volume of gas in the water, immediately made it clear for the students that the volume of gas decreased as the temperature increased, and that this fact consequently made further discussion unnecessary.

Thus, this study indicates that the affordances of computer-simulated laboratories might to a certain extent enhance joint discovery of a scientific concept, but also that furnishing the instructional technology with too complete guidance might risk quenching students' constructive discussions and their discovery process. It is concluded that the decision about what scaffolds should be implemented must be made in relation to the students' pre-knowledge and to how much one intends them to discover by themselves.

The next development for this research is to focus on how our results can contribute to the improvement of the design of virtual laboratories and thereby complement traditional laboratory work.

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