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

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ABSTRACT

Laboratory work in science education is essential for students’ conceptual understanding of natural phenomena. Computer-simulated laboratory experiments have been proposed to facilitate traditional laboratory work. 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 12 dyads’ reasoning about gas solubility in water revealed that the problem was not primarily for the students to realise how the volume of gas changed, but rather 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. The analysis indicates that the affordances of virtual laboratories might, to a certain extent, enhance joint discovery of a scientific concept.

Keywords: Discovery Learning, Gas Solubility in Water, Guiding Structures, Scientific Reasoning, Virtual Laboratory

INTRODUCTION

Understanding natural phenomena is in science education typically equated with the understanding of scientific concepts. Scientific concepts involve specific linguistic distinctions and particular ways of talking about natural phenomena. By using concepts or linguistic tools, one can connect to theoretical traditions and the concepts can be used in different contexts with some meaning preserved. To learn science is therefore to appropriate certain types of discourse and hence the mastery of a specialized language. The most frequent approach to assess students’ understanding of scientific concepts is to use written tests. Inconsistencies in students’ performance on written tests and in interview situations have indicated a gap between students’ written accounts of a scientific concept and their actual understanding of the same phenomenon (Schoultz, Säljö, & Wyndhamn, 2001). Scientific language differs
considerably from everyday language (Lemke, 1990), which is an important aspect to consider when assessing students’ verbal account of a represented concept (Karlsson, 2010). When students reason about a phenomenon visualized by digitalized media, they use their everyday language; teachers, on the other hand, can make use of a scientific language when talking about a demonstrated concept (Ivarsson, 2003).

Students’ understanding of the concept of dissolution of a gas into a liquid, especially when depending on temperature, has been observed by, e.g., Calyk, Ayas, Coll, Unal, & Costu (2007) and Ebenezer & Erickson (1996). Quite contrary to when a solid dissolves in a liquid, there is an inverse relationship between dissolution of a gas into liquid with temperature; i.e., as temperature increases the dissolution of a gas into liquid decreases. Students’ inference from observations of activities is often perceptual and everyday-based, which might for instance result in that they, erroneously, conclude that there is a linear relationship between the temperature and the solubility of a gas in a liquid (Calyk, et al., 2007). Calyk, et al. (2007) found that this may be due to students focusing on the escape of bubbles in a heated liquid instead of on the dissolution of the gas into the liquid, which is not visually observable, and that they are confused about gas into liquid because of what they know from experience about solid into liquid.

A constructivistic approach in 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). Computer-supported collaborative learning does not just take the form of online communication, but is equally concerned with the shared knowledge building going on during face-to-face (F2F) collaboration (Stahl, Koschmann, & Suthers, 2006). Collaborative learning differs from individual learning in the creating and maintaining of a shared response, but also in the aspect of verbalization (Rebetez, et al., 2010). Vygotsky’s (1930/1978) notion of the zone of proximal development (ZPD), which involves collaboration with more capable peers, suggests that the individual learner’s capacity can be enhanced by collaborative work.

Virtual laboratories – digital, simulated laboratory experiments, debated and subject to methodological 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. It can be conducted at a low cost since it does not require laboratory equipment, it need not be done in time-limited periods of classroom schedules and it allows for teaching large numbers of geographically dispersed students. On the downside, the work with simulated laboratories, which yields only programmed outcomes and offers limited screen-based manipulability, does not in the same way as traditional laboratory work support the development of handling skills. In fact, it might even remove the explorative nature and the serendipity connected with traditional laboratory work (Ma & Nickerson, 2006).

Within a joint development and research venture (the Bio-HOPE project within the Wallenberg Global Learning Network program) between Stanford University, Chalmers University of Technology, the University of Gothenburg, and Linköping University, the authors developed a virtual laboratory (available at http://esi.stanford.edu/gasesinwater/gasesinwater1.htm) designed to give students the opportunity to discover gas solubility in water at various environmental conditions. The virtual laboratory constitutes a module in a learning material that deals with the unanticipated impacts of global warming on the salmon population in the Canadian Fraser River, the world’s largest salmon-producing river system. The web-based learning activities, titled “Vanishing fish, Environmental Science Investigation” (available at http://esi.stanford.edu), comprise a free resource providing learners with background knowledge that enables them to explain how the global warming might
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