

Collaborative Learning with Scaffolded Dynamic Visualizations

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Abstract: This study describes collaborative and individual learning for students working with dynamic molecular visualizations. Chemistry students learned about chemical reactions using a week-long project that combined dynamic visualizations with pedagogical tools to support knowledge integration. This study explores how explanation prompts can facilitate collaborative learning with dynamic visualizations using case studies of student pairs. These results have implications for instructional practice with dynamic visualizations and students' use of models and simulations.

Introduction

Dynamic scientific visualizations can help students learn science concepts and inquiry processes in computer-based learning environments. For instance, scientific visualizations enable learners to explore the impact of variables using simulations of complex systems, make complex or emergent processes visible and manipulatable, and enable students to make predictions, test, and refine their understanding. The overall value of instructional scientific visualizations is positive, but there is great variability in learning outcomes (Hoffler & Leutner, 2007). However, there is relatively little research that investigates collaborative learning with scientific visualizations, and the existing research provides mixed results for the impact of visualizations on collaborative learning (Ainsworth, 2008). In some cases, animations may inhibit collaborative learning (Schnotz, Bockheler & Grzondziel, 1999) and in other cases, visualizations may benefit collaborative learning (Rebetez et al., 2009). These varied results may be due to the diverse ways that visualizations are used in instruction, the different designs of visualizations themselves and the domains of the visualizations.

This study builds upon previous work with Chemical Reactions, a Technology-Enhanced Learning in Science (TELS) curriculum unit that combined dynamic visualizations with pedagogical tools in the Web-based Inquiry Science Environment (WISE; Linn et al., 2006). Past research with WISE has found that students who work together in pairs through guided inquiry projects can help each other make sense of science phenomena even when their normative understanding is limited. Students can talk about formative ideas in pairs and offer alternative perspectives and explanations from their teachers or instruction. Students can also build from each other's ideas, helping peers critique and refine their understanding. Students help each other engage in knowledge integration through the process of questioning and explaining instruction.

This paper builds from these studies and explores how guiding small groups' interactions with dynamic visualizations by prompting explanations can impact collaborative and individual learning. Building upon previous research on dynamic visualization, this study explores how prompts that ask students to coordinate representations can support pairs of students to connect ideas. This study explores the explanations generated by students in small groups and how these prompts helped pairs of students connect the visualizations to other related concepts.

Methods

The week-long Chemical Reactions module was designed to help students connect ideas about chemical reactions such as energy, conservation of mass, and limiting reagents on molecular, observable and symbolic levels. A partnership of teachers, researchers and scientists designed and refined the unit to help students elicit, add, revise and reflect upon ideas using the scaffolded knowledge integration metaprinciples of *make science accessible*, *make thinking visible*, *help students learn from others*, and *promote autonomous lifelong learning* (Linn, Davis & Eylon, 2004).

Prior research using Chemical Reactions has tested the efficacy of the curriculum unit involving groups using Chemical Reactions and a comparison group of high school students in chemistry classes (Linn et al., 2006). Increases from pretest to posttests for both the pilot and test groups revealed that students added normative ideas about chemical reactions and made connections among these ideas on symbolic and molecular levels. Regression analysis found that Chemical Reactions students significantly differed from the comparison group, suggesting that students studying the unit outperformed students revising material and retaking the same tests. This study investigates student responses to the embedded explanation prompts about the visualizations to describe the kind of collaborative learning that the prompts may have supported.

Case Studies of Embedded Prompt Trajectories

Selected students' responses based on individual pretest and posttest achievement scores provided a range of the kinds of connections among ideas pairs of students made using the embedded prompts and visualizations. The selection of pairs presented here highlights a range of individual scores from pretest to posttest. This analysis presents a synthesis of the pairs' embedded explanations and corresponding pretest and posttest responses.

Pair 1 both scored above the class average on the pretest and demonstrated strong connections from the visualizations to normative chemistry ideas. For example, when asked about the relationship between the molecular visualizations and the related balanced equations, Pair 1 responded, “They are related because in order to have no atoms left over in the workbench, we had to get a certain amount of oxygen atoms and hydrogen atoms. This number is the same as the ratios in the balanced equation (2 H₂, 1 O₂, and you end up with 2 H₂O molecules).” Pair 1 demonstrated a strong connection between what they have experienced in the visualizations and the concept of balanced equations on a molecular scale. They made connections between chemical reactions and balanced equations through the underlying concept of ratios, and emergent connections between the balanced equation and limiting reagents. Pair 1 significantly gained from pretest to posttest, connecting heat and molecular motion, conservation of mass, and limiting reagents. The explanation prompts may have helped Pair 1 integrate new ideas of conservation of mass and limiting reagents into their repertoire.

Both students in Pair 2 scored below the class average on the pretest. Pair 2’s answers to the prompts demonstrated connections based on color or form from the visualizations to other concepts. For example, when asked about how the balanced equation affects the numbers of product molecules that are made, Pair 2 stated, “You start off with 2purple [sic] molecules, and two blue, bonded molecules. You end up with One purple, and two blu, all bonded.” Pair 2 connected color and number of molecules involved in the activity, but did not connect ideas such as ratios or limiting reagents. The prompts did not seem to help Pair 2 make robust connections to the ideas underlying the visualizations. Pair 2 made very small gains on the posttest and remained under the class average on the posttest.

Pair 3 also scored below the class average on the pretest. Pair 3 demonstrated connections from the visualizations to chemistry concepts in their explanations. For instance, Pair 3 stated, “The balanced equation effected the product molecules by allowing a certain amount of molecules to bond with each other. When some molecules bond with others, some molecules are left alone.” Pair 3 demonstrated emerging connections from the visualizations to the concept of limiting reagents. These kinds of emerging conceptualizations were present in other responses. The prompts seemed to help JG and RB add new information about the visualizations, refine and sort their ideas to make connections to underlying scientific ideas. Pair 3 scores increased from pretest to posttest. Both students demonstrated an increase in their understanding of the connections between the symbolic and molecular representations, conservation of mass, limiting reagents, and the dynamic nature of reactions on the posttest.

In general, pairs that were able to use the embedded prompts to make connections from the visualizations to relevant concepts increased their score from pretest to posttest. These groups demonstrated more integrated understandings of symbolic and molecular representations, conservation of mass, limiting reagents and the nature of chemical reactions.

Discussion and Implications

These case studies illustrate how prompting explanations of the visualizations can help pairs of students make relevant connections from the visualizations to chemistry concepts. These kinds of activities seem to counter the “underwhelming effect” or illusion of understanding that can be associated with dynamic visualizations. By prompting student dyads to explain their understanding of the visualization, students were forced to make their individual assumptions and ideas explicit and engaged in building a shared understanding of the visualization and its meaning. Students sorted out their individual understanding through these discussions with their partners. These results highlight the need for further investigation of the role of metacognition and monitoring of understanding that occurs with collaborative learning with dynamic visualizations.

References

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