Self-Assessment and Self-Explanation for Learning Chemistry Using Dynamic Molecular Visualizations

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Abstract: This poster investigates how self-explanation and self-assessment prompts can help students learn from dynamic visualizations of chemical reactions. We compared students' self-assessments immediately after the visualizations to self-assessments after visualizations plus explanation prompts. Immediately after interacting with the visualization students overestimated their understanding compared to their self-assessments after giving an explanation. Analysis suggests that generating explanations can help students identify weaknesses in their understanding of dynamic visualizations and develop more coherent views.

Introduction

Dynamic visualizations of chemical phenomena have the potential of helping students make connections between molecular, symbolic, and observable views of chemical reactions. Prior studies demonstrate that students often isolate molecular visualizations rather than linking them to existing knowledge or everyday experiences and have difficulty interpreting stand-alone dynamic visualizations (Tversky, Morrison, & Betrancourt, 2002). We have conduced refinement studies to create a module that embeds a dynamic visualization in proven pedagogical patterns (such as predict, observe, develop criteria, explain) and sought ways to improve outcomes. Prior research demonstrates the effectiveness of combining explanations with dynamic visualizations (Pallant & Tinker, 2004) but does not clarify the mechanism. We explore ways that generating explanations can prompt students to build connections among their ideas. Explanations can also help researchers understand how learners interpret visualizations by highlighting disconnected and limited understanding.

To elucidate how explanations help learners link molecular and observable phenomena we placed self-assessments before and after the explanations. The self-assessments illuminate how visualizations and explanations differentially impact the criteria students develop for distinguishing among ideas. This study clarifies how students monitor their understanding of dynamic molecular visualizations and suggests design principles to guide the use of visualizations in chemistry.

Methods

Chemistry students (n=173) in two diverse high schools completed the Technology-Enhanced Learning in Science (TELS) Center 5-day curriculum unit, Chemical Reactions (Figure 1) after covering most chemical reactions topics in textbook-centered activities. This technology-enhanced module uses the Web-based Inquiry Science Environment (WISE) to guide students through an investigation of combustion reactions and their environmental impact (see http://WISE.Berkeley.edu). Students studied the unit in pairs. Teacher 1 ran the project with honors and regular classes, and Teacher 2 ran the project with 2 regular classes in another high school.

Both teachers administered individual paper pretests and posttest to students. These tests included free-response items that allowed students to explain their understanding of everyday, molecular, and symbolic representations of chemical reactions and related concepts such as conservation of mass and limiting reactants. Students self-assessed their understanding of specific concepts on both pretests and posttests.

To investigate how students make sense of visualizations we compared two sequences of visualizations, explanations, and self-assessment prompts. In the *Rating First* instructional sequence students generated ideas, explored a visualization, assessed their understanding of the visualization, and then generated an explanation. In the *Explanation First* sequence students generated ideas, explored a visualization, generated an explanation, and then assessed their understanding. For the self-assessment items, students rated their understanding of specific concepts as poor, fair, very good, or excellent. The explanation prompts asked students how the visualization connected to other concepts or activities. For example, one prompt said, "Explain how the visualization relates to the hydrogen balloon video." Researchers helped both teachers implement the TELS curriculum in all classes. Researchers randomly divided students into Rating First or Explanation First groups within classes on the first day of the project.

Based on the knowledge integration framework (Linn et al., 2006) the scoring of pretests, posttests, and embedded explanation items identified the numbers of connections that students made among ideas. In this study, higher scores represent more connections among representations and/or concepts. Researchers converted the pretest, posttest, embedded notes, and embedded student self-ratings into scores from 1 to 4 (1=poor, to 4=excellent).

Results

Overall, paired t-tests revealed significant gains from individual pretests to posttests across groups. (Pretest: M(SD)=17.2(6.7); Posttest: M(SD)=26.8(7.9); Effect size=1.3, $t(141)=21.8$, $p<.01$). There was no significant impact of teacher or treatment on posttest score. Consistent with their knowledge gains, individual students across all groups rated themselves as more knowledgeable on the posttest than on the pretest, and became more accurate at assessing themselves on the posttest.

Within the chemical reactions unit, the Rating First group consistently rated themselves as more knowledgeable than the Explanation First group (Figure 2). To understand the significance of this observation, we used a 2-level ordinal logistic regression with the embedded self-ratings as the dependent variable and group, question, and the interaction between group and question as explanatory variables. The Rating First group was significantly more likely to rate themselves as more knowledgeable than the Explanation First group ($\beta = -1.49$, $z = -2.20$, $p = .03$). No significant effect of question or interaction between question and rating was found on self-ratings.

Knowledge integration scores for the prompted explanations tended to decrease as students progressed through the curriculum for both groups. On average, students made partial connections from the visualizations to traditional representations, indicating the increasing difficulty of the project and connections that students are prompted to explain. For instance, in one visualization students start with two methane and five oxygen molecules to form carbon dioxide and water. The following explanation prompt asks students how the visualization related to the balanced equation, $CH_4+2O_2 \rightarrow CO_2+2H_2O$. Most students responded correctly about excess reactants in the visualization (1 oxygen molecule or 2 oxygen atoms). Many students connected the "leftovers" with partial ideas about conservation of mass ("you can't gain or lose atoms, so the extra oxygen molecule couldn't be taken away"), ideas about balanced equations ("to balance the equation we don't need one oxygen molecule"), and limiting reactants ("there is not enough to make more"). Some students were able to connect the ratios of the balanced equation to what they had left over ("With the equation above there was 1 O2 left because we had 5. We needed only 4 so we subtracted 4"). However, no significant differences between groups were found on knowledge integration scores.

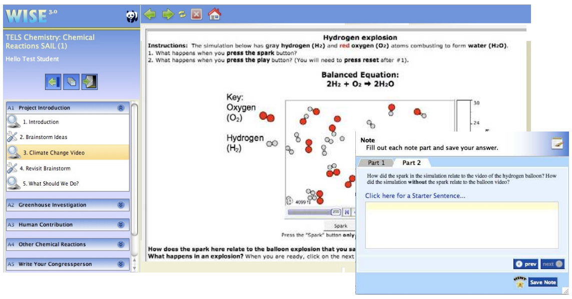

Figure 1. Screenshot of the chemical reactions TELS curriculum unit.

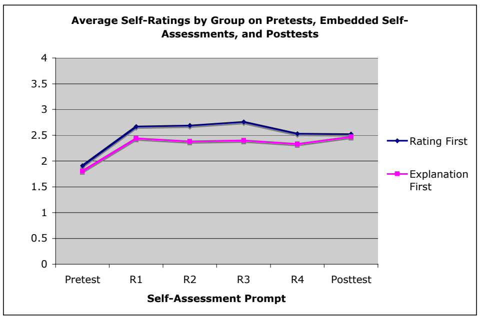

Figure 2. Average self-rating scores by Rating First and Explanation First groups on pretests, embedded self-assessments, and posttests. R1-R4 represent scores for the sequential embedded self-assessment prompts.

Discussion

This study supports a design principle that emphasizes the advantage of combining visualizations and explanations to help students benefit from dynamic visualizations. Students are more critical of their understanding after generating explanations—and likely to seek ways to improve their understanding. Students tend to overestimate their understanding after viewing a visualization. This finding supports the idea that visualizations used without explanations may fail to improve learning because they lull students into complacency. Since the order of self-assessment and explanation prompts had no effect on posttest scores, we conclude that the self-assessments were not necessary to achieve the gain from explanation prompts. Rather, self-assessment prompts helped the researchers understand why combining visualizations with explanations is more successful than visualizations used alone.

References

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