Using Drawings to Support Learning from Dynamic Visualizations

Helen Zhihui Zhang, Marcia C. Linn, University of California-Berkeley, Berkeley, CA 94720-1670, USA
Email: zhzhang@berkeley.edu, mclinn@berkeley.edu

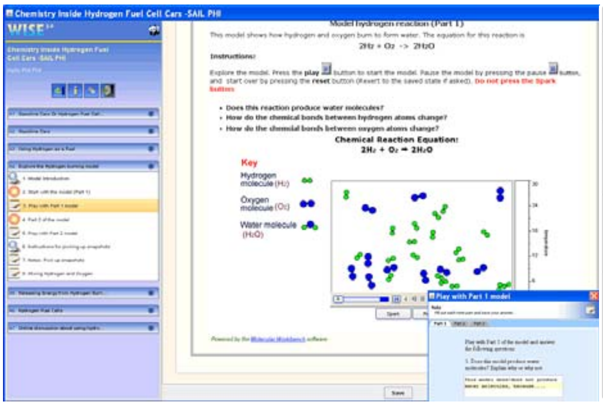
Abstract: Dynamic visualizations can enhance science learning by making unseen processes visible. To study how drawing supports learning from visualizations, the drawing group illustrated their ideas after interacting with molecular visualizations and the interaction group had more time to explore the visualizations. The drawing group learned more and made more precise interpretations of the visualizations than the interaction group.

Introduction

Students often have misunderstandings about chemistry due to the difficulty of translating between symbolic representations, molecular representations, and observable phenomena. Dynamic visualizations can help students connect to the atomic level (Ardac & Akaygun, 2004; Wu, Krajcik, & Soloway, 2001) but may confuse students. Curriculum designers (Quintana et al., 2004) suggested the benefit of scaffolds, such as embedded questions, to strengthen the connections between representations. In this study we explore the use of a drawing activity to scaffold learning from dynamic visualizations embedded in a curriculum module using the Web-based Inquiry Science Environment (WISE, Linn, Davis, & Bell, 2004). The drawing group created paper-based drawings to explain the visualizations, while the interaction group spent more time exploring the dynamic visualizations but did not draw. Assessments included explanation and drawing items aligned with the instruction.

Hydrogen Fuel Cell Cars Module

The knowledge integration framework was used to guide the design and revision of the curriculum module and assessments (Linn, Eylon, & Davis, 2004). The WISE module elicited students' existing ideas about gasoline combustion in cars, and illustrated chemical reactions within the context of hydrogen fuel cell cars. It employed interactive dynamic visualizations of hydrogen combustion at a molecular level and embedded questions (Linn & Eylon, 2006) promoting links between phenomena and representations (see Figure 1). As an example, one embedded question was "Can hydrogen be burned inside the internal combustion engine as gasoline? Explain why." This question required students to connect molecular visualizations with everyday experiences about cars and safety. At the end of the module, students participated in an online discussion comparing hydrogen and gasoline cars that offered students a chance to reflect and reformulate their ideas.



Score	Description
0	**No Answer or Off-task answer.** *Sample answers*: "I don't know." "I guessed."
1	**Incorrect idea/link.** Response has incorrect ideas about chemical reaction or molecular movement, or fails to make correct links between chemical reaction process and molecular movement.
2	**Partial** Have relevant ideas but do not fully elaborate links between them in a given context Sample answers: "no extra energy is added." "both hydrogen and oxygen are found uncombined in nature, as are other elements."
3	**Basic** Elaborate a scientifically valid link between two correct ideas relevant to the context Sample answers: "the reaction hasn't started, so the bonds between H2 and O2 are not broken yet. they are still hydrogen and oxygen molecules."
4	**Complex** Elaborate two or more scientifically valid links among ideas relevant to the context Sample answers: "Before heat is added the hydrogen atoms are connected, moving slowly. However, when the hydrogen gas begins to burn, the temperature increases causing the hydrogen atoms to break apart and move faster. Yet, we are not at that stage yet, so for now they are still connected. The oxygen atoms are connected as well, moving slowly."

Figure 1. *Left:* A screenshot of the dynamic visualizations used in the WISE module. Students use visualizations within steps to add ideas, and use pedagogical tools such as embedded notes to refine their understanding about the visualizations. *Right:* The knowledge integration scoring rubric designed for one assessment item asking to identify the correct molecular representation of reactants.

Methods

This module was implemented in five 8th grade physical science classes (N=133), with three classes in the drawing group (N=81) and two classes in the interaction group (N=52). The same teacher taught both groups. During this five-day (one 40-minute period per day) module, both groups spent the third day working on the same dynamic visualizations and embedded questions. Students in the drawing group completed pictures to show how the burning of hydrogen happens. The interaction group had more time to interact with the visualizations. Many students in the interaction group finished about five minutes earlier than those in the drawing group.

The assessment included pretests and posttests and embedded notes. Students' responses were scored using the knowledge integration framework (Linn, Lee, Tinker, Husic, & Chiu, 2006). Higher scores indicated that students made more complex links between ideas in their explanations. For example, one assessment item asked students to identify the correct molecular representation for the reactants of hydrogen combustion. It assessed whether students could correctly connect the symbolic and molecular representations for the concepts of reactants and molecular movement (see Figure 1 the right part for the knowledge integration scoring rubric).

Results and Discussion

Overall, the teacher implemented the module successfully in all classes. Both groups were similar in terms of prior chemistry knowledge as assessed by the pretest [$t(131) = .05$, $p = .96$]. Both groups made significant progress in understanding chemical reactions by linking representations (see Table 1).

A multiple linear regression analysis [$t = 3.30$, $p = .001$, with a regression coefficient of .30] shows that students in the drawing group integrated more ideas and acquired more precise interpretations of dynamic visualizations than those in the interaction group. Students in both groups started with non-normative ideas about chemical reactions. On the posttest, students in the drawing group advanced to correct ideas and links between the symbolic and molecular representation of bond breaking and formation. Students in the interaction group gained some ideas but few were able to make correct links.

Table 1: Knowledge integration scores of all students, the interaction group and the drawing group.

		Pretest		Posttest			
Group	N	M	SD	M	SD	Effect Size	p
Interaction	52	1.32	.74	2.15	.67	1.32	<.0001
Drawing	81	1.33	.61	2.45	.48	1.71	<.0001
All	133	1.33	.66	2.33	.58	1.53	<.0001

Conclusions

This study investigated the role of scaffolding by exploring the advantage of drawing ideas from dynamic visualizations. Students in the drawing group integrated more ideas than those in the interaction group. The drawing activity scaffolded interpretation of the visualizations by asking students to represent their ideas in a precise, visual format. The visual format increased attention to the molecular reaction process, allowing students to test their ideas about how chemical bonds change. Moreover, the drawing activity helped students reflect on their ideas by comparing their interpretations of the visualizations to the actions on the screen. This research suggests that drawing is a promising way to direct attention to the details of complicated, dynamic visualizations.

Future studies will focus on using students' log files to make the drawing and dynamic visualizations more effective. Logging data can reveal detailed information about students' interactions with visualizations and therefore to offer better guidance to improve learning.

References

Ardac, D., & Akaygun, S. (2004). Effectiveness of multimedia-based instruction that emphasizes representations on students' understanding of chemical change. *Journal of Research in Science Teaching, 41*(4), 317-337.

Linn, M. C., & Eylon, B. –S. (2006). Science education. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of Educational Psychology, 2nd edition.* Mahwah, NJ: Erlbaum.

Linn, M. C., Eylon, B. –S., & Davis, E. A. (2004). The knowledge integration perspective on learning. In M. C. Linn, E. A. Davis, & P. Bell (Eds.), *Internet environments for science education* (pp. 29-46). Mahwah, NJ: Erlbaum.

Linn, M. C., Lee, H.–S., Tinker, R., Husic, F., & Chiu, J. L. (2006). Teaching and assessing knowledge integration. *Science, 313*, 1049-1050.

Quintana, C., Riser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., et. al. (2004). A scaffolding design framework for software to support science inquiry. *The Journal of the Learning Sciences, 13*(3), 337-386.

Wu, H. –K., Krajcik, J. S., & Soloway, E. (2001). Promoting understanding of chemical representations: Students' use of a visualization tool in the classroom. *Journal of Research in Science Teaching, 38*(7), 821-842.