

Depicting Invisible Processes: The Influence of Molecular-Level Diagrams in Chemistry Instruction.

Jodi L. Davenport (jdavenport@cmu.edu)
Katherine McEldoon (katherinemce@gmail.com)
David Klahr (klahr@cmu.edu)
Carnegie Mellon University
Department of Psychology, 5000 Forbes Avenue, BP 342C
Pittsburgh, PA 15213 USA

Keywords: multiple representations; chemistry instruction; diagrams; pictures; multimedia instruction; science learning.

Introduction

Most of what we know about the effects of diagrams in instruction comes from domains in which diagrams depict entities and procedures that are largely accessible to human's unaided perceptual processes (e.g., mechanical systems such as bicycle pumps, drum brakes, pulleys, or the heart and lung system). Instruction that includes diagrams in these domains leads to larger learning gains than instruction without diagrams (e.g., Ainsworth, 2006; Clark & Mayer, 2003). Further, diagrams during instruction may enhance the benefit of self-explanation (Ainsworth & Loizou, 2003). In this study we ask whether diagrams enhance learning in domains such as chemistry, where the diagrams depict entities and processes (i.e., atoms and molecules) that cannot be directly observed, and whose size and number are at a scale that is far beyond students' everyday experience.

Method

Twenty-two participants with introductory chemistry experience were instructed to talk aloud and self explain as they read through a tutorial on acid base chemistry with diagrams (Diagram+Text condition) or identical text without diagrams (Text-only condition). Students completed pretests (definition and multiple-choice questions), read through the tutorial, and completed posttests (definition, multiple-choice and open-ended transfer questions).

Results

Mixed 2 (Diagrams+Text, Text-only) by 2 (pretest, posttest) ANOVAs found that the tutorial significantly improved performance from pre to posttest ($F(1, 20) = 75.26, p < .001$) on definition and multiple-choice questions ($F(1, 20) = 50.73, p < .001$). However, no main effect of diagrams was found for any posttest measure, $F < 1$.

Verbal protocols were coded for self-explanations. A MANOVA found no effect of diagrams on the total number of self-explanations, time on task, or number of words. However, significant correlations were found with the number of self-explanations and transfer performance. For the Text-only group, the total number of self-explanations was positively correlated with transfer test performance, $r =$

.64, $p < .05$. For the Diagrams+Text group, the total number of self-explanations was negatively correlated with transfer test performance, $r = -.62, p < .05$. The pattern of results suggests that diagrams may have invoked familiar but irrelevant information (e.g., Wilkin, 1997).

Discussion

The instructional benefit of diagrams may vary widely with domain and the type of information depicted. Contrary to the robust benefits of diagrams found in prior studies that dealt mainly with diagrams depicting "normal scale" entities and processes, we did not find any diagram benefit for students learning acid base chemistry. Further, students in the Diagram+Text condition appear to have been prompted to produce more shallow self-explanations than students in the Text-only condition. The results suggest that the efficacy of diagrams is likely to be contingent on the domain of instruction and the type of understanding required of the students (e.g., Ainsworth, 2006; Schnotz & Bannert, 2003).

Acknowledgments

Thanks to David Yaron and Michael Karabinos for chemistry expertise. Supported by the Pittsburgh Science of Learning Center (National Science Foundation grant number SBE-0354420).

References

- Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction, 16*(3), 183-198.
- Ainsworth, S. & Loizou, A.T. (2003). The effects of self-explaining when learning with text or diagrams. *Cognitive Science, 27*, 669-681.
- Clark, R. C., & Mayer, R. E. (2003). *e-Learning and the Science of Instruction*. San Francisco: John Wiley & Sons, Inc.
- Schnotz, W., & Bannert, M. (2003). Construction and interference in learning from multiple representation. *Learning and Instruction, 13*(2), 141-156.
- Wilkin, J. (1997). Learning from explanations: Diagrams can "inhibit" the self-explanation effect. In M. Anderson (Ed.), *Reasoning with diagrammatic representations II*. Menlo park, CA: AAAI Press.