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Title

Coordinating Multiple Representations in Scientific Problem Solving: Evidence from Concurrent Verbal and Eye-Tracking Protocols

Reference

Learning & Instruction **2008**, submitted

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Abstract

Although current technology allows for the creation of complex interactive visualizations of scientific concepts, and there is much excitement about the potential of these visualizations for instruction, there have been few studies of how people actually use these new media. Existing studies have used both interactivity logs and verbal protocols to begin examine how students process these complex visualizations. Eye fixation data can complement these measures by providing information about how people allocate their attention to different locations of the visual display, especially when these show different representations of the same phenomenon. We examined how 10 students in an organic chemistry class used an interactive animated visualization that showed different representations on the topic of molecular mechanics, more specifically how mathematical equations are used to model chemical structures and their corresponding energies. Three common energy terms from molecular mechanics were presented as multimodal animations: a 'stretch term' to model bonds between two atoms, a 'bend term' to model angles between sets of three atoms, and a 'dihedral term' to model rotations about bonds. Each frame of the animation showed four different representations – a graph of molecular energy, a ball-and-stick model, and two equations, the general equation and an equation showing the specific values indicated on the graph for that frame. All four representations were synchronized in the animation via an interactive slider. While they were viewing the animations, students were asked questions to probe their understanding of the visualizations. Their eye fixations were monitored throughout the study session, and we analyzed both the verbal and eye tracking protocols.

Students were highly motivated to interact with the animations, spending between 2-3 minutes on each animation, and making several hundred fixations to different regions of the displayed representations. Preliminary analyses of the eye-fixation data indicated that they spent approximately one third (34%) of their time viewing the graph and another third (32%) of their time viewing the molecular model, while spending less time on the equations (11% on the numerical equation and 4% on the general equation). However there were large individual differences in allocation of attention, with one of the students spending as much as 35% of her time on the equations. Notably, the amount of attention to the different representations was highly correlated with how often they were mentioned in the verbal protocols (correlations ranged from .63 to .96) indicating that students' eye fixations and verbalizations reflected similar cognitive processes. We will examine how these individual differences were related to depth of understanding and draw implications for the use of interactive visualizations in instruction.