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EDUCATIONAL RESEARCH

Learning from contrasting molecular animations with a metacognitive monitor activity

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KEYWORDS
Animations;
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Abstract A common problem associated with having General Chemistry students view animations is that students tend to accept the animations as ''correct'' explanations without question or consideration for their limitations. This study proposes a new strategy for presenting animations in chemistry instruction that requires students to critique contrasting animations to determine which animation is a best fit with video-recorded scientific evidence. The purpose of the study was to examine how undergraduate students, enrolled in their first semester of a General Chemistry course, responded to two contrasting animations, one that was scientifically accurate and one that was scientifically inaccurate, as molecular level explanations of a video of a redox reaction involving the reaction between solid copper and aqueous silver nitrate. An analysis of a metacognitive monitoring activity was performed to study how students saw similarities and differences between the animations, as well as, to their own molecular level explanations of the reaction event. The findings revealed that students picked up on the mechanistic differences between the animations, but they struggled with understanding why the reaction happened. Regardless of their background knowledge of chemistry, students voiced preference for animations that were simplistic in their appearance and obvious in what they conveyed while also having an explicit connection to the macroscopic level.

PALABRAS CLAVE
Animaciones;
Química universitaria;
Metacognición;
Ideas de los estudiantes

Aprender de las animaciones de contraste molecular con una actividad de monitorización metacognitiva

Resumen Los estudiantes de Química General tienden a concebir las animaciones de fenómenos químicos como explicaciones «correctas» sin cuestionar sus limitaciones. Este estudio presenta una nueva estrategia para presentar animaciones en clases de química que demanda que los estudiantes critiquen animaciones contrastantes con el fin de determinar cuál de ellas representa mejor la evidencia científica presentada en un video. El propósito de la investigación

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fue el determinar cómo estudiantes de licenciatura en el primer semestre de un curso de Química General respondían a 2 animaciones contrastantes, una de ellas representando de manera científicamente adecuada la reacción redox entre cobre sólido y una solución de nitrato de plata y otra representando el mismo fenómeno de manera inadecuada. Se llevó a cabo un análisis de una actividad de monitorización metacognitiva para estudiar las diferencias y similitudes detectadas por los estudiantes entre las 2 animaciones, así como su propia explicación a nivel molecular del fenómeno observado. Los resultados revelan que los estudiantes fueron capaces de detectar diferencias mecánicas entre las 2 animaciones, pero tuvieron problemas para entender por qué ocurre la reacción. Independientemente de sus conocimientos de química, los estudiantes expresaron preferencia por las animaciones más simplistas y con conexiones explícitas con el nivel macroscópico.

Introduction

When we learn, often times we get things wrong. Many of us would acknowledge that it is normal to have errors in understanding as it is a natural part of the learning process. Unfortunately, repairing inaccuracies in understanding by showing or telling students the correct answers has had limited success. For example, in several animation studies, researchers have found that when students were shown animations and then attempted to draw or explain their new understanding, alternative perceptions persisted (Kelly & Akaygun, 2016; Kelly & Jones, 2007, 2008; Kelly, 2014; Rosenthal & Sanger, 2012, 2013; Ryoo & Linn, 2014; Tasker & Dalton, 2006) and uneven learning was observed. Finding ways to instill deep and meaningful reflection of the information presented in animations has proven challenging. Some researchers have partnered animations with video demonstrations and laboratory activities to bridge better understanding of the relationship between macroscopic and submicroscopic levels (Velázquez-Marcano, Williamson, Ashkenazi, Tasker, & Williamson, 2004) while others have focused on scaffolding animations with guidance and cartoon tutors to assist students in making sense of the animations (Kelly & Akaygun, 2016). But none have intentionally designed visualizations that animate reaction mechanisms incorrectly so that they can be placed in opposition to more accurate animations to challenge students to critique the animations to determine which animation is best, until this study.

Dynamic molecular visualizations

Dynamic visualizations have been investigated quite vigorously in the field of chemistry education for their assistance in improving the viewers' learning of scientific phenomena (Kelly & Jones, 2007, 2008; Kelly & Akaygun, 2016; Kelly, 2014; Kozma & Russell, 1997; Marbach-Ad, Rotbain, & Stavy, 2008; Plass, Homer, & Hayward, 2009; Rosenthal & Sanger, 2012, 2013; Sanger & Greenbowe, 2000; Sanger, Phelps, & Fienhold, 2000). Visualizations explicitly depict unseen processes, such as chemical reactions in order to help learners understand the movement and interactions that are believed to take place (Ardac & Akaygun, 2004; Kozma & Russell, 1997; Ryoo & Linn, 2014; Tasker & Dalton, 2006). However, molecular structures and dynamic processes can be complicated and different representations of the same structure are used by chemists for different purposes. They can also be used by instructors and researchers to emphasize different features (Jones, 2013; Rosenthal & Sanger, 2012, 2013). Kelly and Jones (2007) studied how the features of two different styles of visualizations, affected students' explanations of how sodium chloride dissolves. One of the animations focused meticulously on the dynamics and energetics of the solution process and also showed the lattice to be made of moving ions that vibrated in their lattice positions. While the other animation simplified the look of the solvent and focused on how the water molecules extracted unmoving ions in the sodium chloride lattice. The mix of using both animations improved students' understanding of the functional nature with which water molecules attracted ions and drew them away from the salt lattice; however, learning was uneven and several students retained misconceptions about the nature of salt dissolution and some developed new misconceptions.

Complicated visualizations, while seemingly more scientifically accurate than simplistic animations, have been noted to potentially interfere with student learning (Rosenthal & Sanger, 2012; Ryoo & Linn, 2014). Students can become confused by what they see and have difficulty interpreting complex animations which can prevent them from fully understanding the scientific phenomenon (Mayer, 2001; Rosenthal & Sanger, 2012; Ryoo & Linn, 2014). In contrast, animations that are too simplistic can sometimes influence students to reduce the amount of details they portray in their oral and drawn explanations (Kelly, 2014). The kinds of visualization attributes students recognize as varying from their understanding are typically general characteristics such as structural features and very basic movements. Students expend less attentional effort on detailed features, such as the vibrational movement of ions in a lattice or the complex network of water molecules functioning as a solvent in an aqueous salt solution (Kelly, 2014). In general, animations can help students better understand dynamic molecular processes and researchers should be encouraged to