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The Role of Visual Representations in Impasses During Collaborative Problem Solving in Undergraduate Chemistry

Joel P. Beier, Martina A. Rau
jpbeier@wisc.edu, marau@wisc.edu
University of Wisconsin – Madison, 1025 W Johnson St, Madison, WI 53706

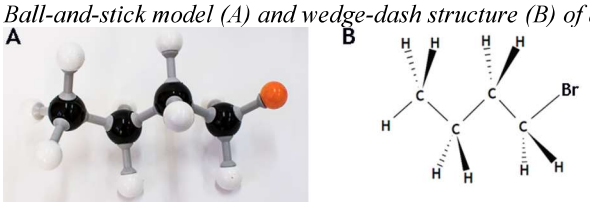
Introduction & Theoretical Background

Visual representations play a key role in disciplinary discourse. They are tools for communicating and problem solving (Wertsch, 1997). Because these representations are part of the community's culture, becoming part of a disciplinary community involves learning representational discourse (Kozma & Russell, 2005). For example, chemists frequently use representations like the ones in Figure 1 to communicate about molecules. STEM communities often use representations in collaborative activities. Representations can enhance the quality of collaboration, and collaboration can help students make sense of how the representations show information (Rau et al., 2017). However, collaboration with representations involves impasses (Strickland et al., 2010).

Impasses are points in a learning trajectory where a student does not know how to proceed because they lack knowledge (VanLehn, 1988). From a cognitive perspective, impasses are learning opportunities if the student receives information on how to proceed (VanLehn, 1988). From a socio-cultural perspective, impasses are opportunities for students to receive guidance on how to align their use of representations with those of more central members of the community (Hutchins, 1993).

Little research has characterized students' use of visual representations to navigate impasses. Hutchins (1993) showed that impasses and the ensuing feedback helps students to gradually align their representation practices with the community's norms. Strickland and colleagues (2010) found that representations can make impasses visible my revealing divergent views on how to solve a given problem. However, it remains unknown how students' use of representations during impasses differs from their use of representations during regular problem solving. To address this gap, we investigate: What is the unique role of visual representations during impasses students encounter during collaborative problem solving?

Figure 1
Ball-and-stick model (A) and wedge-dash structure (B) of a chemical molecule



Methods

We conducted our study in the context of an introductory undergraduate chemistry course. Our study occurred in week 5 of the course, which covered chemical isomerism and used the representations in Figure 1. We randomly selected seven student pairs (n = 14 students) from five lab sessions. All interactions were video-taped.

Students completed ten problems that asked them to construct a ball-and-stick model (Figure 1A) of a given chemical molecule. Then, students modified the ball-and-stick model to show its isomers (i.e., groups of molecules that have the same molecular formula but with different atom arrangements). For each, students had to draw a wedge-dash drawing (Figure 1B). Students collaborated with a partner for about 2.75h.

Videos were transcribed and segmented by turn-of-talk, yielding 8,054 turns of talk. In addition, manipulations of representations and gestures relating to the representations were transcribed. To investigate the role of representations during impasses, we first combined qualitative and quantitative approaches do develop a coding scheme that described students' use of representations and impasses; interrater reliability was Kappa = .90 on 18.6% of the transcripts. Second, we used sequential pattern mining to identify frequent sequences of codes in the transcripts. We defined frequent sequences as those sequences that occurred in at least 65% of the transcripts (i.e., met a support threshold of .65). We ran the sequential pattern mining algorithm separately on the portions of the transcripts that involved impasses (n = 2,731 lines of the transcript) and on the portions without impasses (5,322 lines). This yielded a set of frequently occurring sequences of interactions with representations that characterized interactions with representations during regular problem solving and during impasses. Third, we

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examined the frequent sequences that were unique to impasses using a qualitative approach. This yielded an understanding of students' unique ways of interacting with representations when they encounter impasses.

Results

The grounded theory approach revealed four ways in which students used visual representations during collaborative problem solving. First, students used representations for EXPLORATION when they manipulated a representation while directing their attention to the representation without verbally describing the representation. Second, students used a representation for JUXTAPOSITION when they held the ball-and-stick model adjacent to a wedge-dash drawing for comparison and directed gaze between the representations. Third, students used a representation as a tool for MEDIATION among the collaborating students or between the students and the TA when they manipulated representations while describing related concepts. In these cases, manipulations of the representations were not duplicated verbally. Fourth, students used representations as a REFERENCE to support their arguments when they pointed at a representation. In these cases, students verbalized aspects of the representation. Students most frequently used representations for MEDIATION, followed by REFERENCE and EXPLORATION. Students used representations for JUXTAPOSITION relatively infrequently.

The sequential pattern analysis identified frequent sequences of codes that described students' use of representations. All sequences were unique to either regular problem solving or to impasses. For regular problem solving, we found two sequences: EXPLORATION followed by MEDIATION, and MEDIATION followed by EXPLORATION. During impasses, we found eleven frequent sequences. Six sequences started with REFERENCE (alone or combined with MEDIATION), followed by one to three interactions coded as MEDIATION. Two sequences started with MEDIATION followed by REFERENCE (alone or combined with MEDIATION). The three remaining sequences included two to four interactions coded as MEDIATION and involved no other codes.

Our qualitative inspection of the frequent sequences found for impasses revealed that impasses were usually characterized by one or two students having difficulties interpreting how a wedge-dash structure showed a specific chemical isomer. To resolve the impasse, students used a ball-and-stick model to illustrate the isomer and make sense of isomers by establishing connections between the two representations. In this joint sense-making process, they used both representations as REFERENCE and MEDIATION tools to connect the representations to the underlying concepts until both were satisfied.

Discussion

Taken together, our findings shed light into how representations help students navigate impasses during collaborative problem solving. We found that students use representations as mediators that illustrate aspects that are difficult to describe verbally and as references that disambiguate their verbal descriptions. Using representations in these ways allows students to identify the source of an impasse and to jointly resolve it. Our findings illustrate that impasses engage students actively in joint meaning making with the representations. Future research pending, our findings suggest that joint representation tools may help students learn during impasses.

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