Electronic Supplementary Material (ESI) for Chemistry Education Research and Practice.

Supplementary information

ATTENTION IS CURRENCY: HOW SURFACE FEATURES OF LEWIS STRUCTURES INFLUENCE ORGANIC CHEMISTRY STUDENT REASONING ABOUT STABILITY

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Below are the two case comparison tasks used in this study (Figure 1S). Because similar patterns were observed in the context of both tasks, the main document discusses Task 1 in detail.

Twenty-two students (*n* = 22) were presented with Task 2 and asked to reason about the relative stability of the two Lewis structures. When deciding which resonance form is more stable, 15 students selected A, 5 selected B, and 2 reasoned that both forms are equally stable.

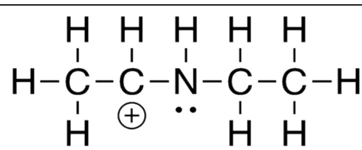
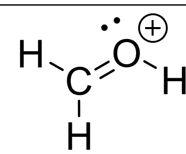
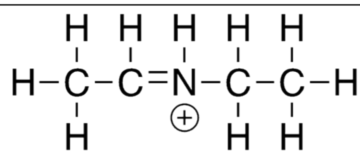
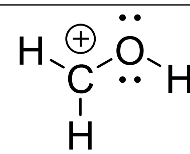
	Task 1		Task 2
A		**A**	
B		B	

Figure 1S. Case comparison tasks of pairs of resonance forms depicted as Lewis structures. The bold green letters represent the more stable structure/resonance form based on the textbook used by students in this study.

Below are the patterns identified for Task 2, organized by research question.

RQ1: What features of Lewis structures do students attend to to identify the most stable structure?

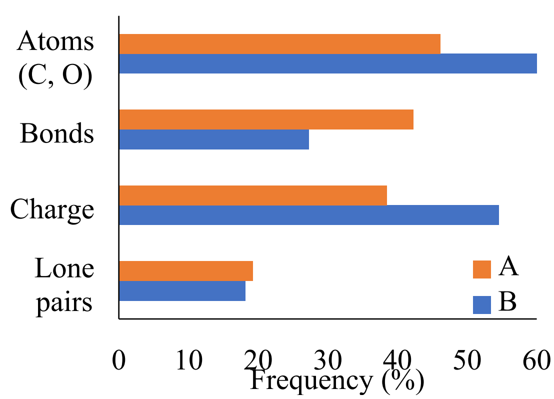


Figure 2S. The frequency with which the students attended to the explicit features of the representations when comparing the relative stability of Lewis structure A (orange) and B (blue).

Similar to Task 1, participants referenced all the explicit features of the provided representations but primarily attributed chemical stability to the unique, eye-catching features of each structure. Structure A was favored as more stable due to double bonds (which is why students who selected A attended to bonds more frequently, Figure 2S), and structure B was thought to be more stable given the charge on the carbon atom (which is why in Figure 2S there are higher frequencies associated with atoms (carbon) and charge for structure B compared to A).

RQ2: What conceptual resources (content-specific knowledge elements) do students activate when attending to the specific features?

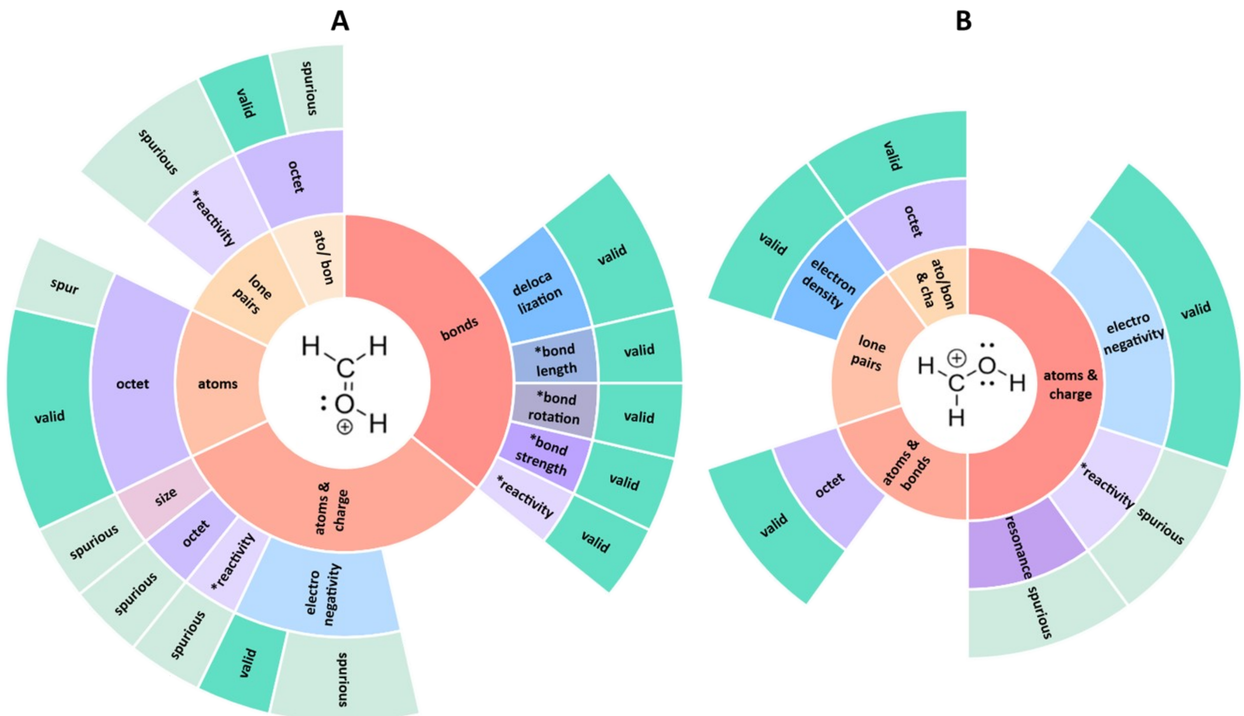


Figure 3S. The surface features of representations (inner ring), the conceptual resources activated (middle ring), and the validity of assumptions (outer ring) associated with the relative stability of the two Lewis structures. Legend: The size of the arc indicates the frequency with which the feature/conceptual resource/assumption was mentioned and not the number of students since one student could mention several features/conceptual resources/assumptions. 'ato/bon' (inner ring in A) stands for 'atoms & bonds.' 'ato/bon & cha' (inner ring in B) represent 'atoms, bonds & charge.'

In considering the factors that contribute to the stability of structure A, students activated conceptual resources related to the double bond (i.e., bond strength, bond length, bond rotation), similar to the findings of comparison Task 1. In both tasks, these conceptual resources were validly referenced but are not productive for this context. Additionally, other conceptual resources such as reactivity, electronegativity, and octet were activated. In all instances for both tasks, reactivity was coded as unproductive as students only discussed explicit features rather than explained the context in which the given structure would undergo a reaction. Similar ideas were discussed related to electronegativity in both tasks but some students mentioned that the size of an atom bearing the charge was an important consideration (Figure 3S). Overall, while the majority of the students selected the correct answer for Task 2, similar to responses to Task 1, some of their conceptual resources were unproductive, and some of their interpretations of chemical principles were nonnormative (Figure 7 and Figure 3S), indicating that correct answers do not always correspond to productive thinking.

When discussing what makes structure B more stable, students activated conceptual resources such as electronegativity, reactivity, and octet and considered the role of lone pairs of electrons in donating electron density to bring about stability (Figure 3S), as had been reported with the comparison Task 1 (Figure 3).

Finally, similar to Task 1, some students only cited explicit features without including any conceptual resources in their explanations (illustrated by the absence of outer rings in Figure 3 and Figure 3S). Additionally, none of the students recognized that the two Lewis structures provided were resonance structures and instead treated the two structures as distinct entities with different structural features and properties. As such, they did not discuss ideas related to major/minor contributors to the resonance hybrid.

RQ3: How do students reason when making inferences about stability from Lewis structures?

Heuristics

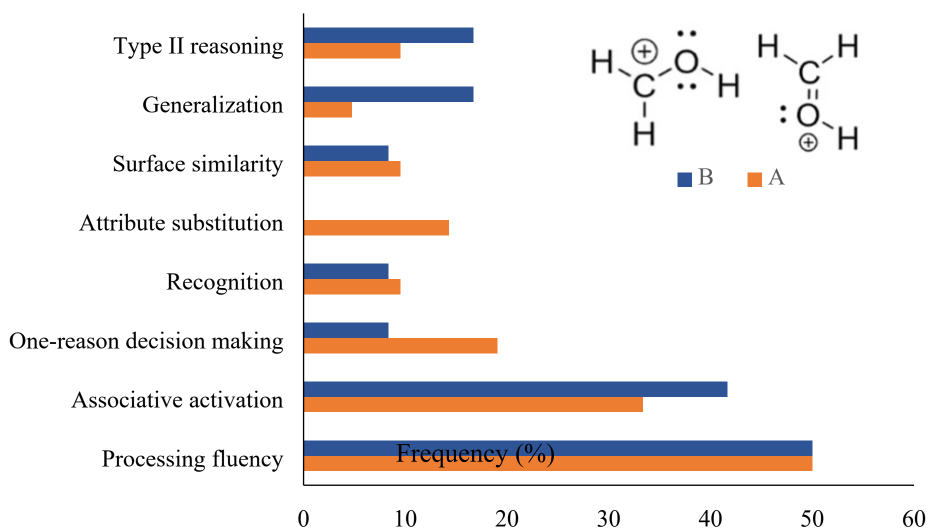


Figure 4S. The frequency of various heuristics and reasoning processes in student explanations.

As observed in responses to Task 1, *processing fluency* and *associative activation* were prevalent heuristics, while other heuristics and Type II reasoning were less common in student explanations to justify what makes a particular structure more stable. In summary, regardless of whether students selected the correct or the incorrect structure as the more stable structure, their explanations included primarily *processing fluency* and *associative activation* heuristics.

Modes of reasoning

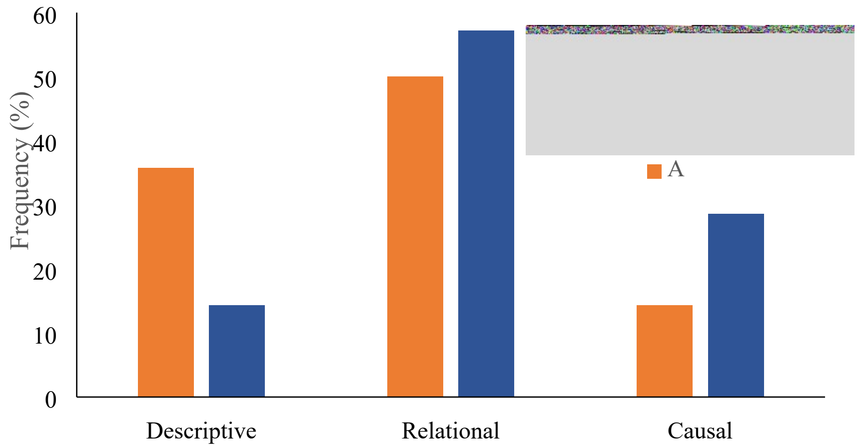


Figure 5S. The frequency with which students provided descriptive, relational, or casual explanations.

Relational explanations were the most frequent and included simple associations between explicit and implicit features without a discussion of *why* or *how* the implicit concepts affect stability. Descriptive explanations were the next most prevalent mode of reasoning, in which students justified their choices by solely referencing explicit features of the provided structures. Additionally, causal explanations were the least common and incorporated discussions of *how* or *why* a particular feature or conceptual resource contributed to stability. Similar patterns were observed for responses to Task 1. Note that even though it looks like students provided more causal explanations for Task 2 (Figure 5S), these causal explanations were expressed by only two students in comparison to one student in Task 1.