Making Energy Easy: Interacting With the Forces Underlying Chemical Bonding Using the ELI-Chem Simulation

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Abstract: We developed and explored four increasing levels of embodied interaction as atoms to support chemistry students in grasping the forces and energy changes involved in chemical bonding. Current results show an increase in students' conceptual understanding in all four levels with the highest learning gain among students who felt the forces using a haptic device.

Vision

This study seeks to develop and explore high-school chemistry students' conceptual understanding regarding forces and energy involved in chemical bonding. Having no access to the molecular world and lacking the force-based explanation of chemical bonding, students rely on incorrect interpretations and intuitive heuristics, such as the 'octet-rule', i.e. eight electrons in the outer energy level (Taber, 2002). Most of them view chemical bonds incorrectly as attached solid spheres for which energy is needed to bring them together, or as coiled springs that release energy when relaxed (Boo, 1998).

We designed and developed an Embodied Learning Interactive environment, ELI-Chem, to alleviate these difficulties: (1) ELI-Chem removes the abstraction by providing bodily experience with the molecular level as proposed by embodied learning theory (Barsalou, 1999); and (2) ELI-Chem is based on a mathematical simulation of attraction-repulsion forces between atoms, supporting a force-based teaching approach (Nahum-Levy et al., 2007; Taber, 2002).

ELI-Chem offers sensory-motor experiences of the attraction and repulsion forces while two atoms approach and move apart, at four increasing degrees of embodiment: (1) *observing videos* that involves no action; (2) *using a mouse* to move an atom in the simulation; (3) *using a joy-stick* that moves a greater distance than the mouse; and (4) *using a haptic device* at greater distance and greater force than the mouse. The first non-interacting degree is a comparison group for the rest. The working hypothesis is that more intense physical experience with the underlying electrical forces provides a stronger foundation for understanding energy changes during chemical bonding and related concepts such as chemical stability or bond-length.

The participants are forty-eight 12^{th} grade chemistry students, 12 in each group. The study is framed as pretest-intervention-posttest design. Main concepts addressed: repulsive and attractive forces, chemical stability, and energy released/required.

Findings show that there was an increase in students' conceptual understanding in all four groups. Three groups - video, mouse and joystick - were indistinguishable in their learning effects. From an explanation based on the 'octet rule' depicting the atoms as static "touching" balls that energy is required to approach them, all groups turned to consider the dynamic balance between attraction and repulsion forces. Adding haptic information to create a multimodal experience of chemical bonding resulted with increased learning gain, indicating on the use of sensorimotor schemes in the building of a more accurate mental models and representations.

References

Barsalou, L. W. (1999). Perceptions of perceptual symbols. *Behavioral and Brain Sciences, 22*(04), 637–660.

Boo, H. K. (1998). Students' understandings of chemical bonds and the energetics of chemical reactions. *Journal of Research in Science Teaching, 35*(5), 569-581.

Nahum-Levy, T., Mamlok-Naaman, R., Hofstein, A., & Krajcik, J. (2007). Developing a new teaching approach for the chemical bonding concept aligned with current scientific and pedagogical knowledge. Science Education, 91(4), 579-603.

Taber, K., & Coll, R. K. (2002). Bonding. In J. K. Gilbert, O. De Jong, R. Justi, D. F. Treagust, & J. H. Van Driel (eds.). *Chemical Education: Towards Research-based Practice* (pp. 213-234). Kluwer Academic Publishers.

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