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From Feeling Forces to Understand Forces: The Impact of Bodily Engagement on Learning in Science

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Overview: Feeling like an atom in a simulated chemical bond with force-feedback increases students' understanding of forces and energy in chemistry.

Audience: Curriculum developers; Formal educators

Key Points

- Learners studying chemical bonding with static representations incorrectly view bonded atoms as non-moving attached balls.
- We developed the ELI-Chem learning environment to provide bodily experiences of the motion and forces that an atom undergoes in chemical bonding.
- Students worked in one of four conditions of motion and force: movie, computer mouse, joystick, and haptic device with force-feedback.
- Enacting an atom increased understanding in all conditions, with greater learning in the haptic condition.
- Bodily experiences of chemical bonding support learning of the involved forces and energy changes.

INTRODUCTION Learners studying the topic of chemical bonding via static representations often fail to understand the simultaneous attraction and repulsion forces acting between the atoms. This dynamic balance between the forces is especially difficult to grasp, as there are no analogs from everyday life for attraction and repulsion happening at the same time in the same place. We developed a computer-based **E**mbodied **L**earning **I**nteractive environment, named ELI-Chem, to represent chemical bonding. ELI-Chem provides bodily experiences as an atom at four increasing degrees of motion and forces, from small palm movements to whole-arm movements against forces. The participants were 48 high school chemistry students, randomly assigned to one of the four conditions – movie, computer mouse, joystick, and haptic device that applies force-feedback. Students' learning gains were assessed by questionnaires, and their written responses in the activity guide were analyzed as evidence of embodied learning.

FINDINGS There was an increase in students' scientific understanding in all four degrees of bodily engagement, with no differences between the first three conditions. Only feeling the forces, the haptic condition, increased students' understanding beyond the other conditions. Feeling the attractive and repulsive forces made the topic more understandable and cogent, in particular the processes of bond breaking and formation.It gave a sense of what an atom experiences - its position, motion, and the changing forces exerted on it. Students' explanations in the haptic condition, included more physical principles rather than naïve ideas and more generalizations compared to non-haptic conditions.

TAKEAWAYS Supporting students' experiences of movement and sensation, which stand at the core of unfamiliar scientific phenomena makes the studied topic more learnable. Thus, when designing a learning environment of abstract phenomena, it is important to situate the underlying scientific principles within an appropriate physical experience. It is important to note that bodily engagement mainly contributes to learning when the concepts are nonvisual, unfamiliar, and the performed movement is aligned to the studied phenomenon