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Developing Ai-based Dynamic Models to Enhance Understanding of Metallic Bonding and Modeling Competence

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Abstract

Modeling in science education is widely recognized as a core pedagogical strategy for fostering students' conceptual understanding and scientific reasoning. However, the electron sea model commonly presented in high school chemistry textbooks accounts only for the particle nature of electrons while neglecting their wave nature and electrostatic interactions. As a result, it fails to fully explain the properties of metals and constrains the development of meta-modeling knowledge for both teachers and students. This study sought to address these limitations by developing a dynamic model of metallic bonding using an artificial intelligence (AI)-based simulation tool. The research involved in-service chemistry teachers enrolled in a graduate science education program. The teachers critically examined the shortcomings of the electron sea model in explaining metallic properties such as electrical conductivity, thermal conductivity, luster, and malleability/ductility. Building on this recognition, they designed AI-based dynamic simulations with HTML and JavaScript, through which each teacher constructed an individualized model of metallic bonding. These models highlighted distinct conceptual aspects, including the wave nature of electrons or the mobility of free electrons. Through this process, the teachers explicitly identified the ignorance embedded in the traditional electron sea model and explored new perspectives for explaining metallic properties more effectively. The findings illustrate the potential of AI- and EdTech-based modeling approaches in teacher education and science classrooms, offering significant implications for the development of instructional strategies that explicitly address the limitations and ignorance of scientific models.

Keywords: Edtech; Meta-Modeling Knowledge; Properties of Metals; Science Education; Simulation