

ORIGINAL ARTICLE

# Implementation of Modeling Instruction in a High School Chemistry Unit on Energy and States of Matter

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## ABSTRACT

Interest in student-centered active learning pedagogies is widespread, but discipline-specific examples of implemented instructional approaches are needed to bridge the gap between pedagogical ideas and their enactment. One of these approaches, Modeling Instruction, is an active, student-centered approach wherein students learn through construction and application of conceptual particle models to understand, interpret, and predict observable phenomena. Here, we demonstrate implementation of Modeling Instruction to teach concepts from an Energy and States of Matter unit in high school chemistry. This preliminary study allowed us to begin to understand the connections between the method, student learning, and student attitudes. Analyses of pre-test, unit exam, and final exam questions provide qualitative support of the method's efficacy. For the two objectives examined here, over 60% of students demonstrated mastery by the end of a unit taught through Modeling Instruction. Semester-long improvements in exam scores suggest that Modeling Instruction facilitates content mastery and retention more effectively than traditional instruction. Finally, anecdotal evidence, particularly insights into student mindset, shows that Modeling Instruction positively impacts the ways students think about their own learning.

**KEY WORDS:** chemistry; constructivism; inquiry-based/discovery learning; active learning; modeling instruction

## INTRODUCTION

Modeling Instruction is a research-based pedagogy wherein students learn through construction and application of conceptual particle models to understand, interpret, and predict observable phenomena. Pioneered by Hestenes et al., Modeling Instruction was first used to teach high school physics in the United States (Hestenes, 1987). The positive impacts of the technique in physics classrooms at the high school and college levels are well-documented (Hestenes et al., 1992; Liang et al., 2012; Malone, 2008; Wells et al., 1995). The more recent implementation of modeling instruction in high school chemistry is timely, as the next generation science standards (NGSS) articulate proficiency in science through the dimensions of disciplinary core ideas, cross-cutting concepts, and practices – placing emphasis on students doing science to learn science (Dukerich, 2015). Rather than memorizing a collection of scientific facts that seems unrelated to newer learners, students learning through Modeling Instruction employ processes similar to those used to realize scientific understanding throughout history. Students make observations and then work individually or in small groups to explain the observations, often using particle diagrams. Explanations are then shared, refined, and used to generate more broad conceptual models.

Based on the well-documented success in physics and the emerging indicators of positive impact in chemistry (Cullen, 2015; Edwards and Head, 2016; Kimberlin and

Yezienski, 2016), we hypothesize that Modeling Instruction is an effective way for students to understand and master content in high school chemistry. We also acknowledge that the implementation of emerging pedagogies is facilitated by practical examples of the approach and its impacts. Thus, in this study, we examine two learning objectives from energy and states of matter unit. Students individually answer a free-response assessment question for each objective in a pre-test, a unit exam, and a cumulative semester final exam. The evolution of students' answers from pre-test to unit exam illuminate students' thought processes as they learn – allowing the teacher to see student misconceptions and to gauge student learning progress. The answers on the cumulative semester final exam give some indication of students' longer-term retention of content knowledge. Comparison of student exam scores over the course of a semester as a function of the instructional method (traditional vs. modeling instruction) demonstrate the impacts of instructional method on student retention and course progress. Together, these results help us understand how modeling instruction impacts the students' learning processes and the efficacy of the method on content mastery and retention, providing preliminary evidence in support of the method's implementation in high school chemistry.

## BACKGROUND

Well-documented and wide-ranging student misconceptions motivate educators to rethink approaches to teaching

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*Energy Modeling for an Uncertain Future* National Research Council (U.S.). Modeling Resource Group Synthesis Panel of the Committee on Nuclear and Alternative Energy Systems, 1978

Model Documentation: Household Model of Energy United States. Office of Energy Markets and End Use, Teaching about Energy John L. Roeder, 2008

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### **Table of Contents Modeling Instruction 20answers Energy**

1. Understanding the eBook Modeling Instruction 20answers Energy
  - The Rise of Digital Reading Modeling Instruction 20answers Energy
  - Advantages of eBooks Over Traditional Books
2. Identifying Modeling Instruction 20answers Energy
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Modeling Instruction 20answers Energy
  - User-Friendly Interface
4. Exploring eBook Recommendations from Modeling Instruction 20answers Energy
  - Personalized Recommendations

- Modeling Instruction 20answers Energy User Reviews and Ratings
- Modeling Instruction 20answers Energy and Bestseller Lists
- 5. Accessing Modeling Instruction 20answers Energy Free and Paid eBooks
  - Modeling Instruction 20answers Energy Public Domain eBooks
  - Modeling Instruction 20answers Energy eBook Subscription Services
  - Modeling Instruction 20answers Energy Budget-Friendly Options
- 6. Navigating Modeling Instruction 20answers Energy eBook Formats
  - ePub, PDF, MOBI, and More
  - Modeling Instruction 20answers Energy Compatibility with Devices
  - Modeling Instruction 20answers Energy Enhanced eBook Features
- 7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Modeling Instruction 20answers Energy
  - Highlighting and Note-Taking Modeling Instruction 20answers Energy
  - Interactive Elements Modeling Instruction 20answers Energy
- 8. Staying Engaged with Modeling Instruction 20answers Energy
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Modeling Instruction 20answers Energy
- 9. Balancing eBooks and Physical Books Modeling Instruction 20answers Energy
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Modeling Instruction 20answers Energy
- 10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
- 11. Cultivating a Reading Routine Modeling Instruction 20answers Energy
  - Setting Reading Goals Modeling Instruction 20answers Energy
  - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Modeling Instruction 20answers Energy
  - Fact-Checking eBook Content of Modeling Instruction 20answers Energy

- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
- 14. Embracing eBook Trends
  - Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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