

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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The World of Matter-energy Paul Franz Brandwein, 1964 *Daily Exercises in Scripture History. Answers, Etc* John Robertson (Headmaster at Upton Park School.), 1878 Contemporary Problems of Architecture and Construction Evgeny Rybnov, Pavel Akimov, Merab Khalvashi, Eghiazar Vardanyan, 2021-03-08 Contemporary Problems of Architecture and Construction 2020 includes contributions on various complex issues and aspects of engineering and construction of buildings and structures protection reconstruction and restoration of architecture as well as intellectualization of energy and safety systems functioning urban development The contributions were presented at the eponymous conference ICCPAC 2020 St Petersburg Russia November 25 26 2020 and cover a wide range of topics Urban development problems of urban construction and architecture Engineering construction and operation of buildings and structures Implementation of building information modeling BIM and geo information systems GIS technologies in the construction industry Energy efficiency of buildings and maintenance systems Engineering technologies of sustainable nature management and environmental protection Intellectualization and algorithmization of large cities road safety systems functioning Economics and management in construction and public utility services Contemporary Problems of Architecture and Construction 2020 will be of interest to academics and professionals involved in the urban development engineering technologies architecture and construction economics and management in construction industry **The Green Factory** Andrea Pampanelli, Neil Trivedi, Pauline Found, 2015-08-22 This book proposes a new model the Lean and Green Business Model L GBM where the environmental aspect of sustainability is integrated with Lean thinking in order to create a way of thinking that contributes to and balances the three sustainability dimensions of people profit and planet The model presented uses a kaizen approach that will *Blended Learning in Engineering Education* Ataur Rahman, Vojislav Ilic, 2018-11-06 Blended Learning combines the conventional face to face course delivery with an online component The synergetic effect of the two modalities has proved to be of superior didactic value to each modality on its own The highly improved interaction it offers to students as well as direct accessibility to the lecturer adds to the hitherto unparalleled learning outcomes Blended Learning in Engineering Education Recent Developments in Curriculum Assessment and Practice highlights current trends in Engineering Education involving face to face and online curriculum delivery This book will be especially useful to lecturers and postgraduate undergraduate students as well as university administrators who would like to not only get an up to date overview of contemporary developments in this field but also help enhance academic performance at all levels *The Church's New Front Door* Daniel Topf, 2024-08-23 The Church's New Front Door introduces Christians to the critically important concept of the Fourth Industrial Revolution an era that will be dominated by powerful technologies like artificial intelligence AI and advanced robotics While the Fourth Industrial Revolution is powered by technological developments it has far reaching political socio economic ethical and spiritual implications as well To be missional the church needs to be

relevant and in order to be relevant in the twenty first century believers must engage with novel technologies and the impact they are having on areas like work education and healthcare Each chapter includes discussion questions and suggestions for further reading making this book an accessible resource for diverse audiences including church members ministry leaders and students at Christian colleges and seminaries Whether you agree or disagree with the author s description of how our world might change in the next ten to twenty years this book will make you think *The Reference Catalogue of Current Literature* ,1940 [Fur-fish-game](#) ,1933 **Frutas y hortalizas** Organización de las Naciones Unidas para la Alimentación y la Agricultura,Centro de Cooperación Internacional en Investigación Agrícola para el Desarrollo,2021-09-20 Este libro convencer al lector de la importancia de las frutas y hortalizas y le har ver que la producci n a peque a escala de estos cultivos es fundamental para alcanzar los objetivos de desarrollo sostenible A lo largo de sus cinco cap tulos el lector conocer los desaf os y las recompensas para los productores los vendedores y los consumidores Cap tulo 1 definici n pr ctica de las frutas y hortalizas y justificaci n del apoyo a los peque os agricultores y las cadenas de valor Cap tulo 2 opciones de manejo agr cola para garantizar que la producci n sea sostenible incluyendo recursos gen ticos sistemas de semillas manejo del agua suelo nutrientes y control de las plagas y enfermedades Cap tulo 3 opciones para integrar a los peque os agricultores comerciales que cultivan frutas y hortalizas en cadenas de valor socialmente inclusivas lo que incluye servicios innovadores de manejo poscosecha v nculos comerciales y reducci n de la p rdida y el desperdicio de alimentos Cap tulo 4 opciones para que los profesionales y los responsables pol ticos de diferentes niveles gubernamentales institucionales y sociales promuevan la producci n y el consumo sostenibles de frutas y hortalizas seguras nutritivas y asequibles Cap tulo 5 intervenciones e innovaciones clave para facilitar la producci n sostenible de frutas y hortalizas en los pa ses de rentas medias y bajas de todo el mundo Esta publicaci n lleva al lector a un viaje present ndole una diversa variedad de frutas y hortalizas a trav s de estudios de casos ilustrados de todo el mundo Contiene argumentos a favor de la importancia de estos cultivos y anima a los lectores a desempe ar un papel activo tanto en la promoci n de la producci n de frutas y hortalizas como a la hora de alentar a la gente a consumirlas [British Books in Print](#) ,1940 **Herausforderung Utility 4.0** Oliver D. Doleski,2017-01-09 Das Buch begleitet den bergang von der analogen zur digitalen Energiewirtschaft und gibt dem Leser wertvolle Impulse f r die Erschlie ung neuer lukrativer Bet tigungsfelder Autoren aus Wissenschaft und Praxis liefern ausgew hlte Antworten auf die enormen Herausforderungen angesichts von Digitalisierung und Dezentralisierung im Energiesektor Insofern soll das Buch Mut machen die digitale Transformation z gig anzugehen und den Ver nderungsprozess insgesamt als Chance zu begreifen Die Debatte um die Ausgestaltung und Zukunft von Utility 4 0 hat damit gerade erst begonnen **Monthly Index of Russian Accessions** ,1959 **Monthly Index of Russian Accessions** Library of Congress. Processing Department,1959 [The British National Bibliography](#) Arthur James Wells,1972 [Applied Data Analysis and Modeling for Energy Engineers and Scientists](#) T. Agami Reddy,Gregor P. Henze,2023-08-15 Now in a thoroughly revised and expanded second edition this

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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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