

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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**National Research Council (U.S.).
Modeling Resource Group Synthesis
Panel of the Committee on Nuclear
and Alternative Energy Systems**

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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* Aatur 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 **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 **British Books in Print** ,1940 *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,2024-10-19 Now in a thoroughly revised and expanded second edition this classroom tested text demonstrates and illustrates how to apply concepts and methods learned in disparate courses such as mathematical modeling probability statistics experimental design regression optimization parameter estimation inverse modeling risk analysis decision making and sustainability assessment methods to energy processes and systems It provides a formal structure that offers a broad and integrative perspective to enhance knowledge skills and confidence to work in applied data analysis and modeling problems This new edition also reflects recent trends and advances in statistical modeling as applied to energy and building processes and systems It includes numerous examples from recently published technical papers to nurture and stimulate a more research focused mindset How the traditional stochastic data modeling approaches are complemented by data analytic algorithmic models such as machine learning and data mining are also discussed The important societal issues related to the sustainability of energy systems are presented and a formal structure is proposed meant to classify the various assessment methods found in the literature *Applied Data Analysis and Modeling for Energy Engineers and Scientists* is designed for senior level undergraduate and graduate instruction in energy engineering and mathematical modeling for continuing education professional courses and as a self study reference book for working professionals In order for readers to have exposure and proficiency with performing hands on analysis the open source Python and R programming languages have been adopted in the form of Jupyter notebooks and R markdown files and numerous data sets and sample computer code reflective of real world problems are available online Applies statistical and modeling concepts and methods learned in disparate courses to energy processes and systems

Provides a broad and integrative structure meant to enhance knowledge skills and confidence to work in applied data analysis and modeling problems Includes practical examples end of chapter problems case studies and RStudio code

Energy Modeling Milton F. Searl, 2016-03-22 In 1973 a seminar was held by Resources for the Future to bring together the new and growing community of scholars researching into the general field of energy modelling Originally published in the same year this report gathers together all of the papers presented at that seminar in order to further spread the results of these studies with those who were unable to attend The papers cover a full range of techniques used for energy modelling whilst commenting on current government and industry models This title will be of interest to students of Environmental Studies

Applied Data Analysis and Modeling for Energy Engineers and Scientists T. Agami Reddy, 2011-08-09 Applied Data Analysis and Modeling for Energy Engineers and Scientists fills an identified gap in engineering and science education and practice for both students and practitioners It demonstrates how to apply concepts and methods learned in disparate courses such as mathematical modeling probability statistics experimental design regression model building optimization risk analysis and decision making to actual engineering processes and systems The text provides a formal structure that offers a basic broad and unified perspective while imparting the knowledge skills and confidence to work in data analysis and modeling This volume uses numerous solved examples published case studies from the author's own research and well conceived problems in order to enhance comprehension levels among readers and their understanding of the processes along with the tools

The National Energy Modeling System, 1994 The National Energy Modeling System NEMS is a computer based energy economy modeling system of US energy markets for the midterm period of 1990 to 2010 NEMS projects the production imports conversion consumption and prices of energy subject to assumptions on macroeconomic and financial factors world energy markets resource availability and costs behavioral and technological choice criteria cost and performance characteristics of energy technologies and demographics This report presents an overview of the structure and methodology of NEMS and each of its components The first chapter provides a description of the design and objectives of the system The second chapter describes the modeling structure The remainder of the report summarizes the methodology and scope of the component modules of NEMS The model descriptions are intended for readers familiar with terminology from economics operations research and energy modeling Additional background on the development of the system is provided in Appendix A of this report which describes the EIA modeling systems that preceded NEMS More detailed model documentation reports for all the NEMS modules are also available from EIA

[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

Modeling Instruction 20answers Energy Book Review: Unveiling the Power of Words

In a global driven by information and connectivity, the ability of words has become more evident than ever. They have the capability to inspire, provoke, and ignite change. Such is the essence of the book **Modeling Instruction 20answers Energy**, a literary masterpiece that delves deep in to the significance of words and their impact on our lives. Written by a renowned author, this captivating work takes readers on a transformative journey, unraveling the secrets and potential behind every word. In this review, we will explore the book is key themes, examine its writing style, and analyze its overall effect on readers.

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