

# Modeling Theory in Science Education

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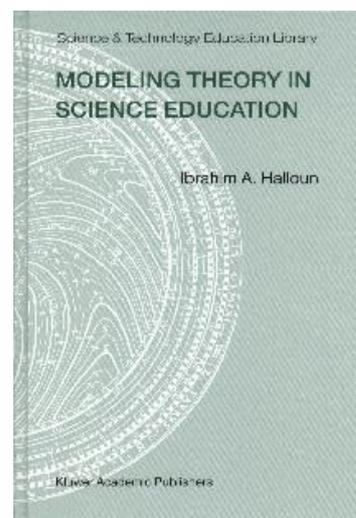
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The book is the culmination of over twenty years of work in the direction of developing modeling theory as a pedagogical theory for teaching and learning science at all levels. It is primarily intended for researchers and graduate students in science education, and it may serve as a major reference for in-service and pre-service science teachers. It focuses as much on course content as on instruction and learning methodology, and presents practical aspects that have repeatedly demonstrated their value in fostering meaningful and equitable learning of physics and other science courses at the secondary school and college levels.



Modeling theory is originally a theory of science, a theory about scientific theory and practice. It basically asserts that models are at the core of any scientific theory and that model construction and deployment are fundamental, if not the most fundamental, processes in scientific inquiry. This book extrapolates modeling theory so as to turn it eventually into a theory of science education, a pedagogical theory that promotes experiential learning of model-laden theory and inquiry in science.

As a theory of science education, modeling theory is presented in the book as grounded in a number of tenets about the nature of scientific knowledge and inquiry, as well as about learning processes in which students ought to be engaged in order to develop meaningful understanding of science. The scientific perspective is offered in Chapter 1 of the book. It emphasizes the central role of models in putting together scientific theory and of modeling in conducting various forms of scientific inquiry. Related cognitive aspects are presented in part in the same chapter and are further developed from a pedagogical perspective in Chapter 3. The emphasis in the former chapter is on the need for students to develop experiential knowledge about physical realities, knowledge that comes about mainly as the result of interplay between people own ideas about the physical world and particular patterns in this world.

Special attention is paid in the book to course content. This interest is driven by the conviction that knowledge organization is crucial for effective and efficient thought and inquiry. It is also implied by the fact that we are catering to science education standards and curricula that continue to be content-driven, which the author asserts is justifiable as long as the drive for process is also there. The focus with regard to content is primarily on models and modeling schemata in the manner discussed in Chapter 2. A scientific model is defined as a conceptual system mapped, within the context of a specific theory, onto a specific pattern in the real world so as to reliably represent the pattern in question and serve specific functions in its regard. A model may serve an exploratory function (pattern description, explanation, post-diction and/or prediction), and/or an inventive function (control or change of existing physical systems to produce the pattern, and/or pattern reification into new physical systems and phenomena). Model constitution and function are laid out explicitly in Chapter 2 and extrapolated to the case of concepts in accordance with specific modeling schemata. A modeling schema serves students as an organizational tool for structuring models or related conceptions in a meaningful and productive way. It also provides teachers with reliable means for planning instruction, and for assessing student learning and teaching practice.

A person's ideas about the physical world are spread across what the author calls a paradigmatic profile. Such a profile consists of a mix of paradigms one of which is dominated by naïve realism. As discussed in Chapter 3, modeling theory in science education is set to help students through a paradigmatic evolution with reasonable expectations. Individual students are anticipated not to achieve a radical paradigm shift in the direction of scientific realism. Instead, they are moved to curtail naïve realism in their paradigmatic profiles and build up scientific realism to realistic levels. Meaningful paradigmatic evolution takes off from a threshold that is attainable by any student willing to invest the necessary effort. The threshold is defined in a given science course by the set of basic models in the scientific theory that is the object of the course. A basic model is a model that provides an affordable and efficient framework for students to develop fundamental tenets and conceptions (concepts, laws, and various theoretical statements) of the respective theory, as well as essential tools and skills of scientific inquiry.

A particular modeling program presented in Chapter 4 is designed to help students achieve the target paradigmatic evolution. The program concentrates on what the author sees as the common denominator among all scientific disciplines: model-laden theory and inquiry. Implicit in the program is the recognition that students at the college and pre-college levels cannot be brought to develop scientific theory and inquiry in uncompromising rigor. The compromise is however significantly reduced through didactic transposition of the content of scientific theory, a transposition that revolves around the set of basic models in the theory. Appropriate activities are designed for students to develop these and other models from different rational and empirical perspectives, and this along with fundamental tools and skills that are necessary for various forms of scientific inquiry. Activities are associated with particular norms and guidelines for a variety of assessment and evaluation processes that allow students to reflect on their own ideas and regulate them in an insightful manner.

The program is implemented in structured learning cycles described in Chapter 5. A learning cycle is presented as a five-phase modeling cycle. The five phases are exploration, model adduction, model formulation, model deployment, and paradigmatic synthesis. Each cycle is devoted to the development of a specific model along with particular modeling processes that can best be developed in the context of the model in question. A cycle takes off with subsidiary models, i.e., counterpart models that have limited viability by comparison to the target model, and that students develop, intuitively sometimes, by correspondence to familiar situations. A cycle proceeds through student-centered investigative activities that allow groups of students to progressively refine their subsidiary models until they take the form of the target model. The entire process is teacher-mediated so as to bring to the surface various student ideas, especially those that are at odds with science, and to help students mutually ascertain their ideas and regulate them in light of empirical evidence and in conformity with scientific theory and practice.

Discussion in the book is often illustrated with examples from Newtonian mechanics, examples that are within the scope of virtually any science teacher and chosen so as to keep an affordable storyline across various chapters. According to the author, modeling instruction as presented in this book has been systematically corroborated, mostly within the context of secondary school and university physics courses, and primarily in U.S.A. and Lebanon. It is now being deployed into other scientific fields and educational levels. Early results are consistent with what has been achieved in the context of physics. They show that the theory in question actually fosters the paradigmatic evolution called for, and that it brings about an equitable learning experience that narrows significantly the traditional gap between students at opposite ends of the competence spectrum, i.e., those students that enter a science course with high competence and those that do so with low competence.

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## About the author

Ibrahim A. Halloun received his PhD in Physics, with a dissertation on modeling in Newtonian mechanics, at Arizona State University in Tempe (ASU) in 1984. He then joined Lebanese University in Beirut, Lebanon. In 1993, he returned to ASU to work on the modeling instruction project there. In 1997, he became science and technology education consultant for UNESCO in Paris.

Prof. Halloun's research has concentrated since the early eighties on the development of modeling theory, first in physics education and then in the broader field of science education. In addition, he has been involved in the evaluation and/or reform of science curricula in many countries around the world. He is author of many standardized assessment instruments and of the Contrasting Alternatives rating scale.

Throughout his professional life, Ibrahim Halloun has attended to a variety of interests of colleagues, students, and administrators concerned with science, mathematics, engineering and technology education. This has enabled him to cultivate rich experience in evaluation, development and implementation of physics and other science curricula (KG-G16), as well as of related teacher-training programs. Some of the materials he has developed have acquired an international reputation.