

## Article

# Models as Epistemic Artifacts for Scientific Reasoning in Science Education Research

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**Abstract:** Models are at the core of scientific reasoning and science education. They are especially crucial in scientific and educational contexts where the primary objects of study are unobservables. While empirical science education researchers apply philosophical arguments in their discussions of models and modeling, we in turn look at exemplary empirical studies through the lens of philosophy of science. The studied cases tend to identify modeling with representation, while simultaneously approaching models as tools. We argue that such a dual approach is inconsistent, and suggest considering models as epistemic artifacts instead. The artifactual approach offers many epistemic benefits. The access to unobservable target systems becomes less mysterious when models are not approached as more or less accurate representations, but rather as tools constructed to answer theoretical and empirical questions. Such a question-oriented approach contributes to a more consistent theoretical understanding of modeling and interpretation of the results of empirical research.

**Keywords:** science education; scientific reasoning; models and modeling; philosophy of science



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## 1. Introduction

Imagine a chemistry teacher trying to explain the volume contraction that occurs when water and ethanol are mixed using the famous demonstration of mixing the corresponding volumes of lentils and beans. Since the contraction of the liquid mixture is a non-trivial consequence of a change in hydrogen bonding length and is not mechanistically explainable by smaller molecules that fill the gaps between larger molecules, the lentil-bean demonstration is clearly misleading. Moreover, another major source of confusion is also simultaneously introduced: molecules are identified with solid spheres while imposing the same identification on single atoms. How is a learner supposed to know when it is appropriate to apply such a structural simplification of volume contraction?

One would expect scientists to be prepared to point out the analogies and simplifications used in the bean-lentil model by stating the assumptions involved. Yet, presenting such assumptions is not a trivial task. Not only should the empirical researchers be able to articulate their own theoretical framework, e.g., psychological constructs or observational premises. Moreover, they would simultaneously need to refer to the specific subject on which, e.g., learning groups acquire knowledge or skills. Instead of such explication work, a representational perspective is often adopted, where the notion of representation is, implicitly or explicitly, understood as a structural or other kind of similarity relation between a model and its supposed target system. But how is one able to understand the lentil-bean example according to such a representational notion of modeling? Indeed, the representational approach cannot easily make room for the fact that models are intrinsically tied to human made inferences, actions, and interpretations, and not just to the natural objects, processes, and systems they study.

Apart from chemistry education e.g., [1–4], the representational approach to modeling is also widely present in other fields of science education research e.g., [5–7]. In its reliance on the representational approach to model-based reasoning, science education research

# Scientific Reasoning And Epistemic Attitudes

**Alessandra Arcuri, Florin Coman-Kund**



## **Scientific Reasoning And Epistemic Attitudes:**

Scientific Reasoning and Epistemic Attitudes László Hársing, 1982      **Scientific Reasoning and Epistemic Attitudes** László Hársing (filozófus), 1982      **Bayesianism and Scientific Reasoning** Jonah N. Schupbach, 2022-03-31 This Element explores the Bayesian approach to the logic and epistemology of scientific reasoning Section 1 introduces the probability calculus as an appealing generalization of classical logic for uncertain reasoning Section 2 explores some of the vast terrain of Bayesian epistemology Three epistemological postulates suggested by Thomas Bayes in his seminal work guide the exploration This section discusses modern developments and defenses of these postulates as well as some important criticisms and complications that lie in wait for the Bayesian epistemologist Section 3 applies the formal tools and principles of the first two sections to a handful of topics in the epistemology of scientific reasoning confirmation explanatory reasoning evidential diversity and robustness analysis hypothesis competition and Ockham's Razor      **Methods in the Philosophy of Science** Sophie J Veigl, Adrian Currie, 2025-07-15 A guidebook to methods and methodology encouraging deeper engagement across the philosophy of science and beyond The last twenty years have seen multiple methodological revolutions in the philosophy of science There has been increased diversity concerning the questions asked who asks those questions who the relevant audiences are and what the techniques and tools involved are In *Methods in the Philosophy of Science A User's Guide* Sophie Veigl and Adrian Currie introduce this range of methods through both practical advice and philosophical reflection Each chapter introduces the reader to a method or set of methods in the philosophy of science discusses its advantages and limitations and provides practical guidance on how to learn skills relevant to applying the method The volume fulfills several critical roles First by introducing and discussing methods in the philosophy of science the collection increases philosophers awareness of methodological options of particular importance for younger scholars who are often not exposed to the diversity of practice Second the collection's practical focus will aid established philosophers in diversifying their own methodological toolkits Third collecting this diversity serves as a ground for philosophical reflection on what we as philosophers take ourselves to be capable of Fourth the collection hopes to increase interdisciplinary links between philosophy and other fields by laying clear the methodological continuity and complement between them      **Information Modelling and Knowledge Bases XI** Eiji Kawaguchi, Hannu Kangassalo, H. Jaakkola, 2000 This is the tenth volume in a series on information modelling and knowledge bases The topics of the articles cover a wide variety of themes in the domain of information modelling design and specification of information systems and knowledge bases ranging from foundations and theories to systems construction and application studies The contributions in this volume represent the following major themes models in intelligent activity concept modelling and conceptual modelling conceptual modelling and information requirements specification collections of concepts knowledge base design and database design human computer interaction and modelling software engineering and

modelling and applications      *A Realistic Theory of Science* Clifford Alan Hooker, 1987-01-01 This book presents a clear and critical view of the orthodox logical empiricist tradition pointing the way to significant developments for the understanding of science both as research and as culture It summarizes the present confused and highly polarized status of the orthodox philosophy of science It exhibits clearly the fundamental metaphysical and global presuppositions and confusions that have led to this status It provides a positive point of view from which progress can be made toward understanding science as research done by real scientists rather than science as exemplifying some prior epistemological program created by philosophers And it leads directly to an understanding of science as a dynamic force within our society with consequences for the environment and public policy      **Springer Handbook of Model-Based Science** Lorenzo Magnani, Tommaso Bertolotti, 2017-05-22 This handbook offers the first comprehensive reference guide to the interdisciplinary field of model based reasoning It highlights the role of models as mediators between theory and experimentation and as educational devices as well as their relevance in testing hypotheses and explanatory functions The Springer Handbook merges philosophical cognitive and epistemological perspectives on models with the more practical needs related to the application of this tool across various disciplines and practices The result is a unique reliable source of information that guides readers toward an understanding of different aspects of model based science such as the theoretical and cognitive nature of models as well as their practical and logical aspects The inferential role of models in hypothetical reasoning abduction and creativity once they are constructed adopted and manipulated for different scientific and technological purposes is also discussed Written by a group of internationally renowned experts in philosophy the history of science general epistemology mathematics cognitive and computer science physics and life sciences as well as engineering architecture and economics this Handbook uses numerous diagrams schemes and other visual representations to promote a better understanding of the concepts This also makes it highly accessible to an audience of scholars and students with different scientific backgrounds All in all the Springer Handbook of Model Based Science represents the definitive application oriented reference guide to the interdisciplinary field of model based reasoning      *The Routledge Handbook of Non-Ideal Theory* Hilkje C. Hänel, Johanna M. Müller, 2024-10-15 Made popular by John Rawls ideal theory in political philosophy is concerned with putting preferences and interests to one side to achieve an impartial consensus and to arrive at a just society for all In recent years ideal theory has drawn increasing criticism for its idealised picture of political philosophy and its inability to account for the challenges posed by inequalities of for example race gender and class and by structural injustices stemming from colonialism and imperialism The Routledge Handbook of Non Ideal Theory is the first handbook or reference source on this important and fast growing debate Comprised of 34 chapters by an international team of contributors the Handbook is divided into three clear parts Methodological Challenges Intersections Applied Issues and Contemporary Challenges Within these sections key topics are addressed including the question of whether non ideal theory is methodologically linked to ideal theory its

intersection with feminist philosophy critical race theory decolonial theory and critical theory its characteristic features the role of the non ideal theorist its relation to activism and its application in the context of disability and health studies climate justice global injustices colonialism and many more As well as a comprehensive introduction which provides important background to the debate between ideal and non ideal theory the Handbook also features a contribution by the late philosopher Charles Mills on non ideal theory as ideology The Routledge Handbook of Non Ideal Theory is essential reading for students and scholars of political philosophy ethics and political theory and will also be of interest to those studying and researching related subjects such as gender race and social justice

**Attitude Measurements in Science Education** Dr. Myint Swe Khine, 2015-04-01 The research into how students attitudes affect learning of science related subjects have been one of the core areas of interest by science educators The development in science education records various attempts in measuring attitudes and determining the correlations between behaviour achievements career aspirations gender identity and cultural inclination Some researchers noted that attitudes can be learned and teachers can encourage students to like science subjects through persuasion But some view that attitude is situated in context and it is much to do with upbringing and environment The critical role of attitude is well recognized in advancing science education in particular designing curriculum and choosing powerful pedagogies and nurturing students Since Noll 1935 seminal work on measuring the scientific attitudes a steady stream of research papers that describe development and validation of scales appear in scholarly publications Despite these efforts the progress in this area has been stagnated by limited understanding of the conception about attitude dimensionality and inability to determine the multitude of variables that made up such concept This book makes an attempt to take stock and critically examine the classical views on science attitudes and explore the contemporary attempts in measuring science related attitudes The chapters in this book are reflection of researchers who work tirelessly in promoting science education and will illuminate the current trends and future scenarios in attitude measurement

*Advanced Learning and Teaching Environments* Núria Llevot-Calvet, Olga Bernad-Cavero, 2018-07-18 In a plural complex and diverse society the school faces many challenges Teachers must prepare their students for future professions unthinkable nowadays and the digital competences of teachers and students are one of the axes of an advanced school This book presents a set of works rigorously elaborated by authors of different disciplines on the role of information and communication technologies ICT in educational centers and on the use of digital resources in the initial and continuing teacher training to improve them as well as in the teaching of different subjects to achieve a better academic and social performance of students Besides the reader will find some innovative experiences in physical education to achieve a better physical emotional and social performance of students

What is a Law of Nature? D. M. Armstrong, 2016-08-26 First published in 1985 D M Armstrong s original work on what laws of nature are has continued to be influential in the areas of metaphysics and philosophy of science Presenting a definitive attack on the sceptical Humean view that laws are no more

than a regularity of coincidence between stances of properties Armstrong establishes his own theory and defends it concisely and systematically against objections Presented in a fresh twenty first century series livery and including a specially commissioned preface written by Marc Lange illuminating its continuing importance and relevance to philosophical enquiry this influential work is available for a new generation of readers      Reconceptualizing the Nature of Science for Science Education Sibel Erduran,Zoubeida R. Dagher,2014-08-20 Prompted by the ongoing debate among science educators over nature of science and its importance in school and university curricula this book is a clarion call for a broad re conceptualizing of nature of science in science education The authors draw on the family resemblance approach popularized by Wittgenstein defining science as a cognitive epistemic and social institutional system whose heterogeneous characteristics and influences should be more thoroughly reflected in science education They seek wherever possible to clarify their developing thesis with visual tools that illustrate how their ideas can be practically applied in science education The volume s holistic representation of science which includes the aims and values knowledge practices techniques and methodological rules as well as science s social and institutional contexts mirrors its core aim to synthesize perspectives from the fields of philosophy of science and science education The authors believe that this more integrated conception of nature of science in science education is both innovative and beneficial They discuss in detail the implications for curriculum content pedagogy and learning outcomes deploy numerous real life examples and detail the links between their ideas and curriculum policy more generally      A Theory of Uncertainty Andreas Klinke,2024-08-02 Using sources from classical to modern that broach the phenomenon of uncertainty and its relation to risk this book creates a novel approach to the recognized but theoretically often unattended issue of uncertainty Andreas Klinke develops a new general theory of uncertainty that provides a taxonomy of categories which are deduced from a critical inventory in philosophy social and natural sciences and risk research Comprising six parts the philosophical grounding of uncertainty sets the stage for the following philosophical and social scientific accounts and explanation of four distinctive guises of uncertainty that form a taxonomic notion and rationale ontological epistemological linguistic communicative and teleological uncertainty The theoretical conceptual rumination provides a complex differentiated view of the anatomy of uncertainty and an understanding that can be used in further theoretical and empirical research as well as socio political practice The latter is delineated in the final part addressing the societal domestication of uncertainty This book will be of great interest to scholars and students in philosophy social and natural sciences risk research as well as inter and transdisciplinary science fields      **Complexity Applications in Language and Communication Sciences** Àngels Massip-Bonet,Gemma Bel-Enguix,Albert Bastardas-Boada,2019-01-11 This book offers insights on the study of natural language as a complex adaptive system It discusses a new way to tackle the problem of language modeling and provides clues on how the close relation between natural language and some biological structures can be very fruitful for science The book examines the theoretical framework and then applies its main principles

to various areas of linguistics It discusses applications in language contact language change diachronic linguistics and the potential enhancement of classical approaches to historical linguistics by means of new methodologies used in physics biology and agent systems theory It shows how studying language evolution and change using computational simulations enables to integrate social structures in the evolution of language and how this can give rise to a new way to approach sociolinguistics Finally it explores applications for discourse analysis semantics and cognition

*A Moral Inquiry into Epistemic Insights in Science Education* Dana L. Zeidler, 2024-09-04 This edited volume reveals a reflective culmination of the Socioscientific Issues SSI framework that examines past present and future trends along with advances in the field of science education It presents for the first time what the precursors and nascent features of the framework entailed and examines the underlying presuppositions that have guided this research program as it matured into present day conceptualizations and cutting edge advances of the SSI framework along with implications for the future More precisely the volume examines what the impetus was for the factors preceding the framework how it came to be formalized into a conceptual and theoretical framework the philosophical sociological and psychological underpinnings of the framework its role with respect to moral education in the context of science education and what it means to pursue moral inquiry and epistemic insight in the practice of science teaching and learning through SSI It offers global insights and perspectives of trends related to SSI from 40 scholars representing 16 nations

**Care & Cure** Jacob Stegenga, 2018-11-13 The author of *Medical Nihilism* examines the philosophical complications and controversies underlying medicine The philosophy of medicine has become a vibrant and complex intellectual landscape and *Care and Cure* is the first extended attempt to map it In pursuing the interdependent aims of caring and curing medicine relies on concepts theories inferences and policies that are often complicated and controversial Bringing much needed clarity to the interplay of these diverse problems Jacob Stegenga describes the core philosophical controversies underlying medicine in this unrivaled introduction to the field The fourteen chapters in *Care and Cure* present and discuss conceptual metaphysical epistemological and political questions that arise in medicine buttressed with lively illustrative examples ranging from debates over the true nature of disease to the effectiveness of medical interventions and homeopathy Poised to be the standard sourcebook for anyone seeking a comprehensive overview of the canonical concepts current state and cutting edge of this vital field this concise introduction will be an indispensable resource for students and scholars of medicine and philosophy Praise for *Care Cure* An exceptionally clear accessible and organized introduction to key concepts and central debates in the philosophy of medicine There is as yet no single author comprehensive introduction to this new field Stegenga's excellent book fills this lacuna Anya Plutynski Department of Philosophy Washington University in St Louis author of *Explaining Cancer Finding Order in Disorder* *Care and Cure* cogently argues that while scholarship on ethics and the practice of medicine are in plenitude there is a dearth of scholarship grappling with a host of other philosophical questions and issues concerning medicine as a discipline A balanced

overview Mark H Waymack Department of Philosophy Loyola University Chicago As an introductory text in the philosophy of medicine *Care and Cure* offers a comprehensive overview of the field which is accessible to beginners in philosophy Notably for a philosophical book on medicine it is not a work in medical ethics but in applied philosophy of science Well written and well structured Stegenga's book is a very welcome addition to the philosophy of medicine literature Hane Maung Department of Philosophy School of Social Sciences University of Manchester *The Territories of Human Reason* Alister E.

McGrath, 2019 *The Territories of Human Reason* is the first major study to explore the emergence of multiple situated rationalities It focuses on the relation of the natural sciences and Christian theology but its approach can easily be extended to other disciplines **Paraconsistent Logic: Consistency, Contradiction and Negation** Walter Carnielli, Marcelo Esteban Coniglio, 2016-06-14 This book is the first in the field of paraconsistency to offer a comprehensive overview of the subject including connections to other logics and applications in information processing linguistics reasoning and argumentation and philosophy of science It is recommended reading for anyone interested in the question of reasoning and argumentation in the presence of contradictions in semantics in the paradoxes of set theory and in the puzzling properties of negation in logic programming Paraconsistent logic comprises a major logical theory and offers the broadest possible perspective on the debate of negation in logic and philosophy It is a powerful tool for reasoning under contradictoriness as it investigates logic systems in which contradictory information does not lead to arbitrary conclusions Reasoning under contradictions constitutes one of most important and creative achievements in contemporary logic with deep roots in philosophical questions involving negation and consistency This book offers an invaluable introduction to a topic of central importance in logic and philosophy It discusses i the history of paraconsistent logic ii language negation contradiction consistency and inconsistency iii logics of formal inconsistency LFIs and the main paraconsistent propositional systems iv many valued companions possible translations semantics and non deterministic semantics v paraconsistent modal logics vi first order paraconsistent logics vii applications to information processing databases and quantum computation and viii applications to deontic paradoxes connections to Eastern thought and to dialogical reasoning **Technocracy and the Law**

Alessandra Arcuri, Florin Coman-Kund, 2021-05-27 Technocratic law and governance is under fire Not only populist movements have challenged experts NGOs public intellectuals and some academics have also criticized the too close relation between experts and power While the amount of power gained by experts may be contested it is unlikely and arguably undesirable that experts will cease to play an influential role in contemporary regulatory regimes This book focuses on whether and how experts involved in policymaking can and should be held accountable The book divided into four parts combines theoretical analysis with a wide variety of case studies expounding the challenges of holding experts accountable in a multilevel setting Part I offers new perspectives on accountability of experts including a critical comparison between accountability and a virtue ethical framework for experts a reconceptualization of accountability through the rule of law



prism and a discussion of different ways to operationalize expert accountability Parts I IV organized around in depth case studies shed light on the accountability of experts in three high profile areas for technocratic governance in a European and global context economic and financial governance environmental health and safety governance and the governance of digitization and data protection By offering fresh insights into the manifold aspects of technocratic decisionmaking and suggesting new avenues for rethinking expert accountability within multilevel governance this book will be of great value not only to students and scholars in international and EU law political science public administration science and technology studies but also to professionals working within EU institutions and international organizations

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