

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

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