

# IMPLICATIONS OF A DEUTSCH-POPPERIAN PERSPECTIVE ON EPISTEMOLOGY FOR MATHEMATICAL MODELING

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## Abstract

We consider what a Deutsch-Popperian perspective on epistemology implies for mathematical modeling to inform decision making. The applications of these models are broad and varied, including topical examples in climate, energy, and pandemic response and preparedness.

Models, within this perspective, are argued to be tools to help generate explanations, and test explanations. Models may provide predictions, but only as a support in the search for explanations. The idea of ‘modeling is for insights, not numbers’ fits well with this perspective.

Furthermore, an implication is that models are not an authority providing justification for action. However, they may be valuable in providing an explanation to support the understanding that underlies action.

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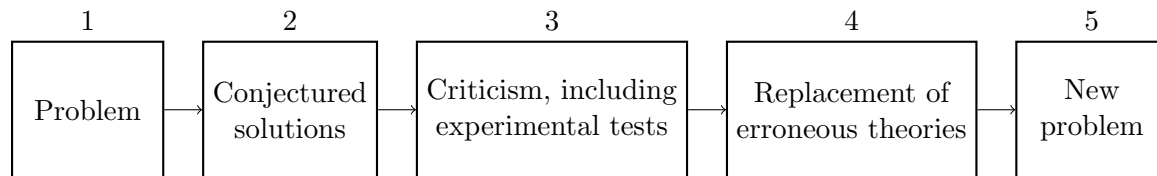


Figure 1: “The course of scientific discovery”: Figure 3-3 from Deutsch (1997)

## 1 Introduction

This short paper asks what the Deutsch-Popperian perspective on epistemology implies for mathematical modeling that inform decisions for policy and strategy. The applications of these models are broad and varied, including topical examples in climate, energy, and pandemic response and preparedness.

The philosophy implies that the goal of modeling should be to create knowledge, through the generation of good explanations. This is in contrast to, or at least subsumes, alternate goals such as the provision of authority or the provision of predictions. On the former, it follows, for example, that the statement ‘modeling shows x is a worthwhile idea for the following reasons’ fits with this goal of modeling better than a statement such as ‘models says x is necessary’. On the latter, consistency with known laws, stylized facts, and predictions may be checked, but given that these models are modeling systems with human agency, a prediction will be more conditional than an explanation.

The implication that the goal of modeling is explanations may seem like common sense and a repetition of the phrase “*modeling is for insights, not numbers*” (Huntington et al., 1982)<sup>2</sup>, but this author thinks important to re-emphasize these common sense notions, and reinforce their foundations. In a practical sense, this paper has been motivated by the use of models in public debate on topics such as climate, as an authority to support narrow prescriptive policy, as opposed to a tool to advance understanding. Meanwhile, placing a central focus on prediction as opposed to explanation may undermine the value of models by clouding appropriate model evaluation techniques.

## 2 Background

Saltelli et al. (2020) succinctly outline problems with models and modeling and present five ways the construction and operation of models may address the problems. Merrick and Weyant (2019) asked for a given modeling application, what is the appropriate resolution of that model. The formulation of a model for an application was left as an upstream question. This paper assesses this upstream question from a Deutsch-Popperian perspective.

This perspective is the articulation by David Deutsch, and subsequent development of, the epistemology of Karl Popper in ‘The Fabric of Reality’ (Deutsch, 1997), and further espoused in ‘The Beginning of Infinity’ (Deutsch, 2011). The associated process of increasing knowledge is represented in Figure 1.

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<sup>2</sup>Hamming (1962) expresses a similar sentiment for computing more generally with “The Purpose of Computing is Insight, Not Numbers”.

## 3 Implications for Modeling

### 3.1 Useful is Problem Solving

In an outline of contributions of Integrated Assessment Models of climate change, [Weyant \(2017\)](#) quotes George Box; “*All models are wrong, some are useful*”. The Deutsch-Popperian perspective allows us to define useful for the purposes of modeling as ‘helps solve a problem’. The goal of creating knowledge through modeling can be operationalized through this framing of solving a problem.

### 3.2 Explanation not prediction

A central argument of [Deutsch \(1997\)](#) is that “prediction - even perfect, universal prediction - is no substitute for explanation”. Prediction may be useful but only to support explanation, which in turn helps solve a problem. This argument aligns with the sentiment that “*Models identify challenges and opportunities in a useful way that is actionable for stakeholders*”.<sup>3</sup>

In the context of [Figure 1](#), models can play a role in the knowledge discovery process and associated explanations through parts (2) and (3) - by helping with the creation and assessment of conjectured solutions, and by playing a role in the criticism process. In contrast to black box predictive models, ‘structural modeling’ that models the relationships between system components may help to illuminate the underlying mechanism of potential outcomes, aiding the generation and testing of explanations.

### 3.3 Explanations that are hard to vary

Given this focus on explanations, what then is a good explanation? A good explanation is defined by [Deutsch \(2011\)](#) as an explanation that is ‘hard to vary’. [Elton \(2021\)](#) discusses how the ‘hard to vary’ concept may be formalized, and distinguishes internal variability from external variability. Internal variability relates to how much the explanation may be varied while producing the same output, while external variability relates to how much the explanation needs to be varied to incorporate new data or facts. The lower each type of variability, the better the explanation.

Models can test proposed explanations by probing both internal and external variability. Established methodologies may be harnessed, for example sensitivity analysis, stochastic optimization, and robust optimization, to test external variability of an explanation to data. As regards internal variability, if a model represents an explanation and alternate models produce the same output it weakens the explanation.

To take an example from the climate / energy policy domain. An explanation may be offered that the only way to meet climate goals is rapid transformation of the demand side through changes in lifestyle, diet, transportation, energy use etc. A model may show that technological progress on the energy supply side could ensure decarbonization may occur with comparatively little change on the demand side. The original explanation was subject to internal variability if the model showed the same climate outcome as the explanation through a different mechanism. Meanwhile, if the

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<sup>3</sup>Weyant, J.P., University of Southern California and Stanford University Symposium on Climate Change Policy and Transportation, November 2020.

original explanation was represented by a model, it could have been subject to external variability, if under a shift in model parameters or in data (for example carbon-free electricity costs), the explanation no longer held.

In this example, models and analysis showed climate goals to be possible and supported understanding of mechanisms, but not provide a technology or policy dictat that must be followed in order to reach said goal.

### 3.4 Embracing conjectural knowledge

If a model does not provide the certainty of the “right” answer, and plays the role of generating and testing explanations, is the exercise still worthwhile? The answer is yes, with the embrace of conjectural knowledge, and the Deutsch-Popperian perspective that all knowledge is conjectural. This conjectural nature is important to those of us who wish to develop knowledge and want to verify models, and communicate their results to policymakers.

Modeling of systems for the purposes of policy and strategy is a different enterprise than, say, theoretical physics or biological sciences, where feedback is shorter and less endogenous, and testing of predictions associated with explanations is more feasible. Yet modeling also may be considered as part of the common enterprise of obtaining knowledge for humankind, with the understanding that all knowledge is conjectural.

With this perspective, assessment of the appropriateness of model formulation to solve problems rests on discussion and criticism.<sup>4</sup> Formal systems and proofs can be helpful for assessing some questions, particularly technical modeling questions, however the higher level questions will rest on this discussion and criticism.

A point outside the scope of this paper, but worth mentioning - if knowledge is conjectural, how can we be certain enough to act? The Deutsch perspective is that human systems should be set up that they can correct errors quickly and efficiently as errors will inevitably occur as conjectural knowledge inevitably hits some bumps as it encounters reality.

## 4 To conclude

Much of this will seem like common sense to many model developers and users of models, and is in line with much modeling practice, however there are many high-stakes examples where models are and were used in a fashion contrary to the ideas outlined here, providing unwarranted authority to decisions, instead of simply supporting decisions.

Setting out an explicit basis for what a modeling exercise can do should guide that these models are as useful as possible in generating knowledge. Others may prefer a different basis, the choice of the Deutsch-Popperian perspective in this paper is based on how it resonates with the experience of this author.

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<sup>4</sup>The Stanford Energy Modeling Forum provides such a platform in the energy modeling space.

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