The Role of Disciplinary Perspectives in an Epistemology of Scientific Models

Mieke Boon
UNIVERSITY OF TWENTE, THE NETHERLANDS

Conference: Metaphysics from a Human Point of View, 26th-28th April 2021

Conference topic:
The impact of perspectivism for the realism—antirealism debate and the metaphysics of science

- My position: Anti-realist – Epistemological Constructivism (rather than Social Constructivism) – Influenced by Hilary Putnam (Reason, Truth and History, 1982), Immanuel Kant, Bas Van Fraassen, ...
- Why?

Introduction (personal: experiences as scientific researcher)

- Point of departure: Philosophical issues in scientific research practices targeting real-life problems (e.g., engineering sciences):
  - Quality of scientific approaches to problem-solving sub-optimal (e.g., reductionist / trial-error).
  - 'Basic' scientific knowledge often not (deductively) applicable (cf. Cartwright).
  - Why is interdisciplinary research so difficult (cf. Nersessian, MacLeod).
- Aim: Develop a philosophy of science for the engineering sciences.
- Hypothesis: Scientific approaches (e.g., methodological choices) are guided and justified by a philosophical picture of science that is (mainly) scientific realist.

Develop a philosophy of science for the engineering sciences.

- My position: Anti-realist – Epistemological Constructivism (rather than Social Constructivism) – Influenced by Hilary Putnam (Reason, Truth and History, 1982), Immanuel Kant, Bas Van Fraassen, ...
- Why reject scientific realism and adopt anti-realism?
### Rough and dirty

| Reality                  | Anti-realism (epistemological, not metaphysical) |
|--------------------------|--------------------------------------------------|
| **Definition**           | According to Van Fraassen, the statement of scientific realism is: Science aims to give us, in its theories, a literally true story of what the world is like; and acceptance of a scientific theory involves the belief that it is true. Van Fraassen's anti-realist alternative is that the central aim of science is the empirical adequacy of theories, rather than their truth, and that the belief involved in accepting a scientific theory is only that it 'saves the phenomena.' 'Truth' as a semantic notion only applies to common-sense observable world. |
| **Philosophical argument** | • Miracle argument  
• Inference to the best explanation (IBE, Peter Lipton)  
• Theory-change  
• What theories say (the 'true story') cannot be observed (common sense) in real world  
• Truth of theories cannot be proven (logic)  |
| **Normative ("What is at stake")** | • Warrant objectivity  
• Avoid relativism  
• Naive (philosophical) beliefs about science hamper quality of scientific practices  
• Adequate epistemologies needed to promote quality |
| **Intuitive**            | • Ontology: there exists order in the world.  
• Scientific theories (and models) represent what the world (behind the phenomena) is like  
• Role of the human cognitive system and specificities of the research practice in the construction of 'order,' theories, concepts, ... epistemic tools. |

### Philosophical method / approach to developing epistemology

| Practice oriented (context dependence): | Focus on scientific models in research practices (esp. engineering sciences) => criteria for acceptance epistemology are adequacy, relevance, usefulness, etc |
|----------------------------------------|--------------------------------------------------------------------------------------------------|
| Epistemological issues:                | Scientific modelling  
• What and how do models represent?  
• How are models constructed and justified?  
• How do models allow for epistemic uses (e.g., inferential reasoning)?  
• How to evaluate different models of 'the same' phenomenon: challenges of interdisciplinary research. |
| Kantian / Kuhnian (transcendental & pragmatic): | Philosophical theories to explain / account for "how ... possible?"  
• a) What must be presupposed about human cognition, epistemic entities, and scientific practice to answer this?  
• b) Focus on epistemology (not metaphysics). |

### Research questions for an epistemology of scientific models: Transcendental & pragmatic approach

- **My position:** **Anti-realist** – Epistemological Constructivism (rather than Social Constructivism) – Influenced by Hilary Putnam (Reason, Truth and History, 1982), Immanuel Kant, Bas Van Fraassen, ...
- **Why reject scientific realism and adopt anti-realism?**
- **Anti-realist stance is demanding on developing plausible Philosophy of Science & Epistemology.**
- **Philosophical method / approach?**

- **"How ... possible?"**
  1. "How is it possible that models represent non-observable target-phenomena?"
  2. "How is it possible that humans gain knowledge about aspects of reality by scientific models?"
  3. "How is it possible that scientific models allow for epistemic tasks and inferential reasoning by humans?"
  4. "How are scientific models justified?"
- "What must be presupposed about scientific practices, the character of epistemic entities (e.g., models), and human cognition to explain that this is possible?"

---

**Develop a philosophy of science for the engineering sciences.**

Contra Van Fraassen Aim of science is epistemic tools, rather than theories.

**Focus:** Epistemology of scientific models
**Philosophical method / approach to developing epistemology**

| Practice oriented (context dependence): | Focus on scientific models in research practices (esp. engineering sciences) => criteria for acceptance epistemology are adequacy, relevance, usefulness, etc. |
|----------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Epistemological issues:**            | Scientific modelling  
  a) What and how do models represent?  
  b) How are models constructed and justified?  
  c) How do models allow for epistemic uses [e.g., inferential reasoning]?  
  d) How to evaluate different models of 'the same' phenomenon: challenges of interdisciplinary research. |
| **Kantian / Kuhnian (transcendental & pragmatic):** | Philosophical theories to explain / account for “how ... possible?”  
  a) What must be presupposed about human cognition, epistemic entities, and scientific practice to answer this?  
  b) Focus on epistemology (not metaphysics). |
| Philosphical results:                   | Epistemologies & Schemas for analysis of  
  a) Scientific models and model [re]construction (B&K method for analysis)  
  b) Disciplinary perspectives (Kuhnian framework for analysis) |

**Scientific realism:** Scientific model is (or aims to be) a literal (although idealized and simplified) representation of its target.  
- Supports similarity account of scientific models

---

**What and how do scientific models represent?**

Giere's (2002) similarity account of representation

“Models are objects that can be used to represent reality by exhibiting a designated similarity to physical objects ...”

“My prototype for a model is a standard road map. This is a physical object (usually made of paper) that I would say represents a terrain in virtue of quite specific spatial similarities. I move on to scale models, such as Watson’s original physical model of DNA.”
What and how do scientific models represent?

Giere's (2002) similarity account of representation

Similarity account does not help to explain how models are constructed and used. Moreover: How does the scientific model of DNA enable and guide inferential reasoning, e.g. about how to interact with real-world DNA?

- Scientific realism: Scientific model is (or aims to be) a literal (although idealized and simplified) representation of its target.
- Supports similarity account of scientific models
- Conclusion: Similarity account of representation is problematic when the target phenomenon is not observable in a straightforward (common sense) manner.
- Which phenomenon does the model represent? (this is confusing me):
  - the model describes the observed phenomenon, or,
  - the model describes the theoretical phenomenon that supposedly explains the observed phenomenon.

Similarity between Model and World? = Model represents = similarity between model and real-world target?

What and how do scientific models represent?

Anti-realist position is (more) demanding on epistemology.
**What and how do scientific models represent?**

*Giere's similarity account of representation*

1. The target-phenomenon is usually not observed in a straightforward (context-free) manner, and requires characterization in terms of measurable variables and subsumption under (scientific) concepts.
2. The identification of the target-phenomenon and the construction of the scientific model is guided and also confined by the disciplinary perspective within which researchers in a scientific discipline have learned to work.
3. Epistemology of models requires analysing the construction of models ⇒ B&K method for (re)construction of scientific models (Boon&Knuuttila 2009).
4. ...
Explaining Sonoluminescence

Emission of a light pulse from imploding bubbles in a liquid when excited by sound.

Reconstruction of the scientific model for "Single-bubble sonoluminescence"

1) Technological problem-context? None – Discovered phenomenon. Later: e.g., Sono-chemistry.
2) The phenomenon (X) for which the 'model for X' is produced? Light-flashes of bubbles in standing sound-wave.
3) 'Epistemic purpose' of the model? Models are 'tools for thinking'. Causal-mechanistic models often are used for thinking about possible interventions, e.g., in the context of experiments or technological applications.
4) Model type? Causal-mechanistic as it presents the physical mechanism by which the phenomenon X is produced. Additionally, mathematical model is developed to predict and test in experiments.
5) Relevant (physical) circumstances and properties? The kind of fluid and gas (composition of the gas); the frequency and energy of the sound-wave; the pressure and temperature of the liquid; bubble radius; etc.
6) Measurable (physical) variables? [In addition to the above]: Intensity of the light-flash, spectrum and wavelengths of the emitted light, etc.
7) Idealizations, simplifications, and abstractions? E.g.: “we have assumed that the liquid is isothermal and so have neglected the equation for the fluid temperature. As an approximation, the bubble’s extension compared to that of the flask and that of the sound wave is neglected, as it is orders of magnitude smaller.”
8) Theoretical and empirical knowledge, and principles, used in the construction of the model? Many theories are used – also see next slide -- e.g.: Classical theory of bubble dynamics; theory of cavitation collapse; ...
9) Hypothesis: Light-flash is caused by adiabatic heating of the bubble at collapse, leading to partial ionization of the gas inside the bubble and to thermal emission such as bremsstrahlung.
10) Justification of the model: Justification is part of modelling. Additionally: (a) comparison of measured variables with model predictions (calculations); (b) measuring effects of variations in relevant circumstances (5).

Develop a philosophy of science for the engineering sciences.

• My position: Anti-realist – Epistemological Constructivism (rather than Social Constructivism) – Influenced by Hilary Putnam (Reason, Truth and History, 1982), Immanuel Kant, Bas Van Fraassen, ...
• Why reject realism and adopt anti-realism? Besides philosophical, also normative / pragmatic reasons:
  • To promote the quality of scientific research &
  • To better understand (cognitive & practice challenges of) interdisciplinary collaborations in scientific research to solve real-life problems: Role of disciplinary perspectives.
Disciplinary perspectives on a multifaceted problem

1. Intrinsic aims and objectives related to what is considered the subject-matter of research in the discipline,
2. Research questions typical of the discipline,
3. The types of real-world phenomena (observable and non-observable) typically investigated in the discipline,
4. Fundamental (ontological) principles, basic assumptions and beliefs used in the construction of scientific models and the conceptual articulation of non-observable phenomena,
5. (Theoretical) conceptual frameworks and empirical (phenomenological) knowledge accepted in the discipline, including specific scientific concepts indicating observable and non-observable phenomena, and other technical terms,
6. Measurement instruments and procedures used in the discipline,
7. Epistemic and pragmatic criteria that epistemic results such as scientific models should meet,
8. Representational means typical of the discipline,
9. The target-phenomenon is usually not observed in a straightforward (context-free) manner, and requires characterization in terms of measurable variables and subsumption under (scientific) concepts,
10. The identification of the target-phenomenon and the construction of the scientific model is guided and also confined by the disciplinary perspective within which researchers in a scientific discipline have learned to work,
11. Epistemology of models requires analysing the construction of models => B&K method for (re)construction of scientific models (Boon&Knuuttila 2009),
12. A Kuhnian framework to systematically articulate the disciplinary perspective of a practice, which also allows for critical assessment (and interdisciplinary communication) of the perspective.