Scientific Practice: A Tool's Perspective

We have learnt about three topics in philosophy of technology up to now, namely thought experiments, models & scientific representations and computer simulations. Reflecting on what we talked about in the past lectures, we can easily find that scientific practice often goes beyond the traditional trichotomy of theories, observations and experiments and employs various tools. This is because it's almost impossible to confirm a theory through a direct experiment in most times, and that it takes a wide variety of indirect methods for modern science to prove a complicated one.

Nowadays, many scientific practices are performed with surrogative reasoning[1], which means reasoning on one thing (e.g. a model) to draw justified or plausible conclusions about something else. Thought experiments, for instance, can be regarded as a typical method of this kind of reasoning. A thought experiment is an imaginary scenario that is meant to elucidate or test an argument or theory. It is often an experiment that would be hard, impossible, or unethical to actually perform. It can also be an abstract hypothetical that is meant to test our intuitions about morality or other fundamental philosophical questions.[2] Some famous experiments in modern physics, such as Schrödinger's cat, Maxwell's demon and Einstein's elevator, are thought experiments. The trolley problem in ethics, psychology and artificial intelligence[3], is also a thought experiment. Besides, it's notable that such experiments have existed for more than two centuries. Experiments like Galileo's falling bodies and Newton's bucket in classical physics are also thought experiments.

Another common kind of surrogative reasoning is computer simulations, which are the running of a mathematical model on a computer, the model being designed to represent the behaviour of, or the outcome of, a real-world or physical system. They have become a useful tool for the mathematical modeling of many natural systems in physics (computational physics), astrophysics, climatology, chemistry, biology and manufacturing, as well as human systems in economics, psychology, social science, health care and engineering. Usually, the reliability of the outcomes of computer simulations can be determined by comparing their results to the real-world outcomes they aim to predict.[4] Some famous examples of them include computer simulation of Molecular Dynamics, Monte Carlo simulation and General Circulation Model (GCM).

In the following of this paper, I'll take thought experiments as an example, present the main philosophical issues related to them and then describe the philosophical approaches aimed at solving these issues. Finally, I'll judge these approaches with concrete case studies.

The current main philosophical issue about thought experiments is an epistemological debate, namely how merely experimenting in thought can provide new knowledge of the natural world. It arises from Kuhn's question in 1964, i.e. how a thought experiment can lead to new knowledge or to new understanding of nature relying exclusively upon familiar data. To tackle this issue, one must answer two questions: one is what kind of insight thought experiments can provide, which is to analyze the epistemic good a thought experiment can deliver; the other is how thought experiments provide what they provide without any new empirical data and how they justify this insight. Below we'll talk about two philosophical approaches, which have opposite opinions on the question of whether thought experiments transcend empiricism or not. Brown believes thought experiments do, known as Platonic intuition-based account of them, while Norton believes they don't, known as argument account of them.

Brown

Brown argues that thought experiments can transcend empiricism, thus we humans can learn about abstract entities like scientific laws as well as mathematical objects through Platonic intuitions, thereby acquiring priori knowledge.[5] Concretely, he classified thought experiments into destructive and constructive ones, and the latter can be further classified into direct, conjectural and mediative ones. Besides, the combination of destructive and direct ones forms Platonic thought experiments.

Destructive Thought Experiments

Three subtypes of destructive thought experiments exist. The first one is when the experiment draws out a contradiction in a theory, thereby refuting it. For example, Galileo's falling bodies example shows the intrinsic contradiction in Aristotle's account. The second is when the experiment aims to show the theory in question conflicts with other beliefs we hold. Schrödinger's cat doesn't show the internal inconsistency of quantum theory but shows that it conflicts with some common beliefs we have about macro-sized objects. The last subtype is when a central premise of the thought experiment is undermined, i.e. negative thought experiments. For instance, Thomson showed that "right to life" and "right to what is needed to sustain life" had been run together with such a subtype of thought experiment.

Constructive Thought Experiments

Constructive thought experiments are to provide a kind of illustration that makes a theory's claims clear and evident, in which they serve as a kind of heuristic aid.

Mediative Thought Experiments

A mediative thought experiment is one that facilitates a conclusion drawn from a specific, well-articulated theory. And there are various ways to get this done. A mediative thought experiment may demonstrate some highly counterintuitive aspects of the theory to make it more acceptable; or it may act like a diagram in a geometrical proof which helps to understand the formal derivation and even be essential to discover the formal proof. Maxwell's demon is a perfect example of this type of thought experiment.

Conjectural Thought Experiments

In a mediative thought experiment, we start with a given theory and the experiment serves as a midwife to draw out a new conclusion. However, there are times when we don't start from a given theory, and the point of such a thought experiment is to establish some phenomena and postulate a theory to explain them. This is known as a conjectural thought experiment, in which we are encouraged to conjecture an explanation for the phenomena emerging in it. Newton's bucket is an example of such an experiment.

Direct Thought Experiments
Direct thought experiments resemble mediative ones since they start with unproblematic phenomena, but they don't end with it, like conjectural ones. Galileo's falling bodies experiment is also an example of such experiments.

Platonic Thought Experiments
Now we have found that a small number of thought experiments fall into two categories: they are simultaneously destructive and direct. Galileo's falling bodies experiment is the case, which did two distinct things: one is destroying Aristotle's view, and the other is establishing a new account for the phenomenon. The combination of the two gives rise to Platonic thought experiments.

In Brown's opinion, according to Platonism, we can intuit some mathematical objects, and mathematical objects are abstract entities. Thus, we can (at least in principle) intuit abstract entities. According to the realist account of laws of nature, laws are also abstract entities. Thus, we might be able to intuit laws of nature as well. There is one situation in which we seem to have special access to the facts of nature, namely in thought experiments. Thus, it is possible that thought experiments allow us to intuit laws of nature. Intuitions are no sensory perceptions of abstract entities. Because they do not involve the senses, they transcend experience and give us a priori knowledge of the laws of nature.

Norton
Norton characterizes thought experiments as follows: thought experiments are arguments which: (i) posit hypothetical or counterfactual states of affairs, and (ii) invoke particulars irrelevant to the generality of the conclusion. And to recover sufficient conditions for a thought experiment from the characterization, the nature of the particulars in (ii) would have to be specified more closely. They must be of a type sufficient to guarantee the appropriate experimental character to the argument.

In Norton's view, firstly thought experiments in science can always be reconstructed as arguments based on explicit or tacit assumptions that yield the same outcome, one basis for which is empiricism. While thought experiments teach us about the world, empiricism tells us that they can only do so by drawing on our experience of the world. The result of a thought experiment must be the reformulation of that experience by deductive or inductive argumentation, which preserves truth or its probability. Another independent basis is that no thought experiment in science cannot be reconstructed as an argument up to now, including those in the literature as resistant to such reconstructions.

Secondly, Norton claimed that the actual conduct of a thought experiment consists of the execution of an argument. To be precise, the epistemic reach of a thought experiment coincides exactly with that of an argument, thus it doesn't dominate the argument in this aspect. Thought experiments are not epistemically superior to their corresponding non-thought-experimental arguments and vice versa. We cannot learn things from a thought experiment over and above the things we can learn from its associated argument. Then there is no point to adopt the view that a thought experiment can transcend empiricism.

Based on this, Norton presented his elimination thesis: thought experiments are arguments which contain particulars irrelevant to the generality of the conclusion. Thus any conclusion reached by a good thought experiment will also be demonstrable by an argument which does not contain these particulars and therefore is not a thought experiment. The thesis contains two steps. The first is that a thought experiment is reconstructed as an argument that refers to particulars, and the second is that we could be able to transform such an argument into an argument that doesn't refer to any particular.

There are two readings of this thesis. The weaker reading claims that we can eliminate some details in a given scenario and change others, i.e. some of the experimental details are irrelevant to the generality of the conclusion and a similar experimental arrangement could provide the same general conclusion. Such a reading is about the conclusion but not about the process leading to it. The stronger reading claims that thought experiments could in principle, even difficult in practice, be replaced by non-thought-experiment-arguments, i.e. all particulars are eliminated in the non-thought-experiment-argument that should replace the thought experiment. This reading is about the conclusion as well as the process leading to it.

In my view, I prefer Brown's Platonic intuition-based account of thought experiments to Norton's argument account. Here I'll take the double dart throw thought experiment, a striking elaboration of Brown's Platonic intuition-based account, as a case study. It's originally associated with Freiling's axiom of symmetry. In this scenario, one imagines two darts thrown at random onto the real unit interval [0,1]. We then define a function f mapping each point in [0,1] to a countable subset of [0,1]. After the first dart lands at x, it is intuitively almost certain that the second dart, landing at y, does not fall in the countable set f(x), since such sets have Lebesgue measure zero.[6] By symmetry, since the order of throws should not matter, Brown argues one should also anticipate $x \notin f(y)$. This yields the axiom of symmetry, equivalent to the negation of the Continuum Hypothesis, grounded in non-empirical probabilistic intuition about abstract sets.

This reasoning bypasses any appeal to sensory data or formal deductive chains. It instead relies on a kind of Platonic perception of measure-theoretic facts. On the contrary, Norton attempts to show that every thought experiment can be reduced to an empirical-premised deductive or inductive argument. Yet the double dart throw thought experiment eludes such reduction. The probabilistic symmetry insight, the intuitive awareness that almost all pairs (x, y) satisfy the symmetrical condition, is not derivable from any empirical premise; it is grasped immediately through intuition. That is exactly Brown's view: certain high-level mathematical insights arise from direct, non-empirical cognition of abstract structure rather than from sensory or calculational inference. [7] Therefore, the experiment supports Brown's opinion that thought experiments can yield priori knowledge, while challenging Norton's claim that they are merely disguised arguments.

To summarize, the nature of Norton's view is trying to reject thought experiments as experiments that can bring about new insight and consider it only as another form of existing data and knowledge. However, Brown's work has spared no effort to prove the creativity of thought experiments, showing that they can also act as what other types of experiments can do.

References

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