



Taming theory with thought experiments: Understanding and scientific progress



Michael T. Stuart

Center for Philosophy of Science, University of Pittsburgh, Cathedral of Learning, Room 817Q, Pittsburgh, PA, 15260, USA

ARTICLE INFO

Article history:

Received 20 November 2015
Received in revised form
7 April 2016
Available online 6 May 2016

Keywords:

Scientific understanding;
Thought experiments;
Scientific progress;
Maxwell's demon;
Einstein's clock in the box;
Darwin's vertebrate eye

ABSTRACT

I claim that one way thought experiments contribute to scientific progress is by increasing scientific understanding. Understanding does not have a currently accepted characterization in the philosophical literature, but I argue that we already have ways to test for it. For instance, current pedagogical practice often requires that students demonstrate being in either or both of the following two states: 1) Having grasped the meaning of some relevant theory, concept, law or model, 2) Being able to apply that theory, concept, law or model fruitfully to new instances. Three thought experiments are presented which have been important historically in helping us pass these tests, and two others that cause us to fail. Then I use this operationalization of understanding to clarify the relationships between scientific thought experiments, the understanding they produce, and the progress they enable. I conclude that while no specific instance of understanding (thus conceived) is necessary for scientific progress, understanding in general is.

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When citing this paper, please use the full journal title *Studies in History and Philosophy of Science*

One only understands the things that one tames.

—A fox (Saint-Exupéry, 1943)

I claim that one way thought experiments enable scientific progress is by increasing understanding. To make this claim, I need to say something about what understanding is. Despite philosophical interest,¹ there is no currently accepted characterization of understanding. The most general characterization defines understanding as any epistemologically desirable state that is not knowledge. But this needs to be more specific if it is to do any philosophical work. Some philosophers characterize understanding as whatever a good explanation provides (e.g., Salmon, 1984; but see Lipton, 2009 for counterexamples). Others as

what we get when we reduce the number of fundamental entities that we have to admit in a theory (e.g., Friedman, 1974), or what happens when we find a way to explain different phenomena using the same patterns of argument (Kitcher, 1981). Henk de Regt characterizes understanding in terms of intelligibility, which is “the value that scientists attribute to the cluster of virtues (of a theory in one or more of its representations) that facilitate the use of the theory for the construction of models” (2009, p. 31). Hasok Chang claims that understanding “is knowing how to perform an epistemic activity” (Chang 2009, p. 75). This definition brings us to the ongoing debate concerning whether understanding is a type of knowledge. For example, Lipton (2004) argues that understanding is knowledge of causes, and Grimm (2006) argues that it can be Gettiered. But while many agree that whatever understanding turns out to be, it will be a kind of knowledge (Achinstein, 1983, p. 23; Kitcher, 2002; Salmon, 1989, pp. 134–5; Woodward, 2003, p. 179), others are not so sure (Elgin, 1996, 2004; Kvanvig, 2003; Zagzebski, 2001).

Deciding between these definitions isn't necessary for my purposes. All I need is a way of picking out intuitive instances of understanding to show that thought experiments can provide

E-mail address: m.stuart@pitt.edu.

¹ E.g., Achinstein (1983), De Regt (2009), De Regt and Dieks (2005), De Regt, Leonelli, and Eigner (2009), Elgin (1993, 2004), Friedman (1974), Kitcher (1981), Kosso (2006), Machamer and Woody (1994), Salmon (1984), Toulmin (1972), van Fraassen (1980), and Woodward (2003).

something like what we get in those instances. I will pick out instances of understanding by using the following consideration: we already can, and do, *test* for understanding, both in ourselves and in our students. There are at least two kinds of test that we use to do this.

1. Two tests of understanding

The following two tests can be identified in many fields of study.

In the first, we are asked to demonstrate a grasp of the meaning of a concept, idea, or theory. This type of test may come in the form of true/false questions, matching questions, multiple choice questions, definition questions, short answer questions, or (the first half of) an essay. Consider a few examples:

- 1) True or false? A valid argument must have all true premises.
- 2) Which of the following is *not* one of Aristotle's four causes?
- 3) What is constructive empiricism?

In order to answer these questions correctly, we need to have semantic relations established between the ideas in question and our existing ideas, concepts, and experiences. For the first question, we have to connect the concept *VALID* with some logical definition, and ask ourselves what that definition says about true premises, which itself requires that we know what premises are, and so on. Establishing such relations is one of the central aims of education.

My first claim is that the epistemic state that enables us to answer questions of this type is understanding. If we were looking for knowledge, we might ask for something like a list of justified true beliefs. Instead, this type of question asks for evidence of semantic digestion. If we could *only* repeat the textbook definition of some concept, theory or model, we can't be said to understand it, since in this case, we could only answer questions that require exact repetition of that definition. Such repetition would count as a display of knowledge, but not understanding, and the semantic question type usually asks for more than this. True/false, multiple choice, and compare and contrast questions require the ability to make distinctions and draw relations within and between concepts. If I can't say how constructive empiricism differs from realism or positivism, I probably don't understand constructive empiricism.

The strongest evidence for this sort of understanding is the ability to put a theory, concept or model in our own words, and explain it to others. If I can do this, then at some point I must have interpreted the new idea with respect to my existing ideas and experience. Oral examinations and job interviews require so much preparation because they are among the most fine-grained tests of this sort of understanding.

In any case, honest success with *any* of the above question types requires the existence of meaningfully formed relationships between new ideas and existing ones. Let's call the set of tests that primarily rely on the establishment of semantic relations, tests of *meaningfulness*.

We encounter a second kind of test for understanding when we are asked to *do something* with an idea, concept, theory or model. This kind of test might require that we argue for a conclusion, derive a result, play a piece of music, or disassemble a handgun. Passing this sort of test requires that the new idea have found its way into our cognitive toolkit. In other words, we must be able to achieve something that we could not have achieved before, or could not have achieved as efficiently without using the new idea. For example, I may have been able to provide moral arguments for abortion, but I might not have been able to do so explicitly using utilitarian reasoning. And this sort of ability is partially what is

required to say that I understand utilitarianism. Call the set of tests that require us to demonstrate a new ability, tests of *fruitfulness*.

For full marks, most written tests require that we display both sorts of understanding. First we show that we understand the new ideas in terms of the relations between them and our previous ideas and experience. Then we are asked to do something with them.

Finally, the fact that we have a range of grades for success in these two endeavours reflects the fact that there are grades of understanding. The more deeply we've sewn a new idea into our doxastic quilt, the better. And the more problem types to which we can apply the new idea, the better.

A few caveats. It is still possible to pass both types of test without having any real understanding. Tests are always imperfect, and there are as many ways to fake understanding as there are knowledge. I introduce these tests, therefore, merely as a way of operationalizing understanding: we have the experience of passing these two types of test, we know what it feels like to transition from encountering a new term for the first time, coming to grasp its meaning (shallowly then deeply), and learning to use the new term, theory or model to do something.

Second, there will be genuine instances of understanding that this operationalization does not capture. However, all I need for my argument is that if *S* has the ability to pass these two tests (to some minimally high degree) with respect to *p*, then we have reason to think that *S* understands *p* (to some minimally high degree).

Third, there may be relations between the cognitive states tested by each of the two tests. For example, it might be the case that to pass the fruitfulness test, we must also be able to pass the meaningfulness test. I do not want to make any claims about such relations at this time. Finally, while I am interested in the cognitive mechanisms required to pass these tests, I make no claim about them here.²

My main argument in this paper is the following. Some thought experiments enable understanding in that they help us to pass the meaningfulness test and the fruitfulness test. Being able to pass these tests is necessary for scientific progress. Therefore, some thought experiments can enable scientific progress by increasing understanding. The first premise is supported by case studies. The second by a short argument along the following lines: it is *prima facie* plausible to think that we cannot make progress with a new scientific idea if we do not know what it means and cannot achieve anything with it.

I should say that the arguments in this paper are orthogonal to most of the existing literature on thought experiments. It has generally been granted since Kuhn (1977, p. 263) that thought experiments contribute to scientific progress, although there are skeptics.³ Scientific progress can be understood as the accumulation of new propositional knowledge (as in Bird, 2007, 2008), and some philosophers (including Brown, 2004, p. 34; Gendler, 2004, p. 1152; Kuhn, 1977, p. 241; Norton, 2004, p. 44; Thagard, 2010, p. 251) have discussed the way that thought experiments might make this possible. Another way to characterize scientific progress is as an increase in understanding (as in Bangu, 2015; Dellsén, 2016), and some philosophers have discussed the way that thought experiments increase understanding (e.g., Arthur, 1999; Camilleri, 2014; Gendler, 1998, 2000; Gooding, 1993, 1994; Humphreys, 1993; Lipton, 2009; Nersessian, 1992, 2007). None of these, however,

² In Stuart (forthcoming) I argue that one thing necessary for passing both tests is imagination.

³ These include Meinong (1907), Duhem (1954, pp. 201-205), Dancy (1985), Harman (1986), Thagard (2010, 2014) and Wilkes (1988). For replies, see e.g., Häggqvist (1996, chap. 2) and Stuart (2014).

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