Formal Reconstructions of Scientific Reasoning

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What is *mathematical philosophy*? Mathematical philosophy is consists in the use of mathematical tools (such as logic) to shed light on philosophical questions. How can mathematical philosophy be "applied"? Once a particular problem of philosophical interest is identified, mathematical tools can help us to explore and understand the structure of the problem, its possible causes and effects, among others of its components.

1 Science and Scientific Reasoning

1.1 Science: Problem solving enterprise

- Scientific theories/models/groups of propositions are not individuated abstractly, but in terms of specific problem solving goals.

  Types of problems: *Empirical*: not fulfilled predictions, "surprising" phenomena,... *Conceptual*: contradictions, vagueness, scope, ...

- A scientific theory (model/group of propositions/...) will be successfully *individuated according to a particular problem*, if the set of propositions that constitute such a theory (or model) **entails a solution to the problem,** or a statement of the problem as well as a neat, or systematic understanding of it.[1]

- A particular theory (or model) A will be distinct from another theory (or model) B according to a particular problem if and only if the solution of the problem that is entailed by the theory (or model) B cannot be achieved without the theory (or model) A. Two distinct theories (or models) could be *satisfactorily combined* if and only if they are distinct theories and if their combination allows for larger explanatory or predictive power, solving other problems or contribute to greater understanding, than the one that each theory alone possesses.

Scientific reasoning (problem solving):

[1] For related notions of *problem solving* see Laudan (1977)

- Sensible reasoning: Agents are still able to distinguish between the (inferential) products of their reasoning that are sensible given a particular context from those that are not.

- Successful inferential patterns: Chains of inferences that help to achieve particular goals in an optimal way, and what is optimal depends on the phenomenon that is being studied, different types of reasoning aim at different goals.

  Goals: (i) successful ways through scientists could entail satisfactorily statement(s) of X (ii) successful ways through scientists could entail a solution of X [2] (iii) a successful way to avoid specific problems.

1.2 Styles of Reasoning (i)[3]

From:

- *Ideas*: (1) questions, (2) background knowledge, (3) systematic theory, (4) topical hypotheses, and (5) modeling of the apparatus.

  Things: (6) target, (7) source of modification, (8) detectors, (9) tools, and (10) data generators.

  Marks and the manipulation of marks: (11) data, (12) data assessment, (13) data reduction, (14) data analysis, and (15) interpretation.

To:

- The simple postulation established in the mathematical sciences,
- The experimental exploration and measurement of more complex observable relations,
- The hypothetical construction of analogical models,
- The ordering of variety by comparison and taxonomy,
- The statistical analysis of regularities of populations and the calculus of probabilities, and
- The historical derivation of genetic development.

1.3 Styles of Reasoning (ii)

- "[N]arrow styles of reasoning, central to these activities is the activity of inferring—different ways of inferring—appropriate conclusions, whether they are concerned with phenomena or instruments and apparatuses." (Bueno 2012, 659)

[2] What counts as a solution is often contextual

[3] See [Bueno 2012]

- "Narrow styles of reasoning can be characterized in terms of the mechanisms they provide to represent what are perceived as possibilities in a given domain of inquiry, and to draw inferences from these possibilities (together with additional assumptions) about the domain in question."(Bueno 2012,660)

- "The accepted information about the domain need not be true; the only requirement is that it is *accepted*." (Bueno 2012, 660; my emphasis)

Task1: Present a problem and, appealing to different styles of reasoning, provide a solution for it. Finally, explain why you consider such combination of inferential paths to be succesful.

2 Formal Reconstructions

- **Rational Reconstructions play an important philosophical role for the understanding of scientific activity**

  Considering the fact that history is not necessary itself explanatory, at least since Lakatos, it has been explicit that the way in which philosophers tend to gain understanding of historical episodes is through the analysis of rational reconstructions of such episodes. Rational reconstructions constitute attempts to provide explanations of why certain scientific events took place in the way they did. These reconstructions are not only empirical (historical) data, but also a particular way to put that data together; they are shaped by both empirical elements and methodological constraints, which jointly determine to a very large extend the choice of problems that could be philosophically worth to analyze (Lakatos 1978).

  (General) Philosophical purpose of rational reconstructions: To provide explanations of why certain scientific events took place in the way they did.

- **Formal Reconstructions of Scientific Reasoning are descriptions of the most natural inferential procedures that scientists use when solving problems in science.**

  Realistic reconstructions of scientific inconsistent reasoning of historical cases of alleged inconsistent science should allow for descriptions of the most natural information-transmitting procedures that scientists use (and have used) when dealing with contradiction. These type of reconstructions should be explicative of how scientists were lead to consider as sensible certain inferential products given a particular context – rather than to be explicative of what causes those results to be (partially) true.[4]

[4]For a similar view see Harman (1984).

Task2: Analyze the following case study. Identify the problem that is being solved and, appealing to styles of reasoning, propose a reconstruction of the reasoning that underlies the following practice:

- **Case study:** The Liquid Drop Model and the Shell Model contain incompatible basic principles regarding the structure of the nucleus of an atom; it is only when nuclear physicists combine some of the predictions of both models that they gain accuracy in their predictions and measurements of binding energies for all the chemical elements of the periodic table and in their predictions and explanations of other nuclear processes such as fission. This case study illustrates a scenario in which each model can accurately predict only a segment of the elements in the periodic table and only part of a general phenomenon, but in which combining the predictions of both models provides successful descriptions and predictions of more general phenomena.

- **Despite its efficiency, the Rational Reconstructions-approach faces some problems.**

  • First, as has been shown in the literature, there are too many different approaches as to what makes a rational reconstruction a good one, for instance, which epistemic values are pursued when explaining a historical episode and which are the methodological desiderata that aim to be fulfilled when doing so. • Second, when dissimilar reconstructions are provided to explain the same scientific episode, it is not clear how to rank those epistemic values in such a way that can help us to fairly compare the reconstructions to one another. • Third, it is not clear when two different reconstructions of the same episode are actually rivals and when they could complement each other and allow for a better understanding of the historical moment that they are describing.

Homework: Briefly, reconstruct a case study (from your own discipline) that illustrates problem solving reasoning and explain it using styles of reasoning.

3 References

1. Otávio Bueno (2012): "Styles of reasoning: A pluralist view", Studies in History and Philosophy of Science Part A 43 (4):657-665.

2. Gilbert Harman (1984): "Logic and reasoning", *Synthese* 60: 107–127

3. Imre Lakatos (1978): "History of science and its rational reconstructions", in *The Methodology of Research Programme* Cambridge University Pres: 102.

4. Larry Laudan, L. (1977): *Progress and its Problems: Towards a Theory of Scientific Growth*, University of California Press.