Theoria, 2019, 34(3), 317-320
https://doi.org/10.1387/theoria.21108

THEORIA

ISSN 0495-4548 – eISSN 2171-679X

Guest editors' introduction[&]

(Introducción de los editores)

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[&] For comments and discussions, we are grateful to all contributors to this special issue and to the anonymous referees that helped in improving the contributions. Thomas Sturm's work was supported by the Spanish Ministry for the Economy, Industry and Competitiveness (MINECO) through the research project *Naturalism and the sciences of rationality: an integrated philosophy and history* (FFI2016-79923-P).

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How to cite: Sturm, Thomas; Nickles, Thomas. (2019). «Guest editors' introduction»; *Theoria. An International Journal for Theory, History and Foundations of Science,* 34(3), 317-320. (https://doi.org/10.1387/theoria.21108).

Received: 11 September, 2019; Final version: 11 September, 2019.
ISSN 0495-4548 - eISSN 2171-679X

Innovation is connected in many different ways to science—from the development of new theories, methods, instruments, standards of scientific rationality and even scientific institutions to the invention of new technologies and social practices that are themselves, in turn, dependent on newly emerging scientific knowledge. We are familiar with studies analyzing innovation as marketable products of scientific work; but the concept of innovation as applied to science itself is of relatively recent origin and less discussed in philosophy of science, and so, therefore, are interactions between innovation in science and innovation through science. Last but not least, funding bodies, research applications, and assessments of scientific research are using the terminology of innovation more and more. In all of this, the language is often unclear and confused, if not abused or overblown. That situation needs to change. The present special issue aims to overcome this neglect by contributions using general philosophical reflections as well as case studies from interdisciplinary perspectives.

Against this general background, the articles are guided by three groups of questions:

> (1) What *is* innovation within science itself? Is it different from technological innovation, including "translational" science, or from science-driven social innovation? Can and should we transfer social, economic, biological and other scientific theories of innovation (being the original sources of the concept) to the domains of science studies, including philosophy of science?
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> (2) By what methods or processes are scientific innovations achieved? Can we develop rational accounts of innovations? What are the socio-historical, technological, and cognitive conditions that support or inhibit innovation in and through science? Can we develop philosophical frameworks using "innovation" (and related concepts) for a new account of scientific change beyond cumulativist or non-cumulativist theories, i.e., in contrast to standard realist accounts of discovery, on the one hand, and antirealist accounts (e.g., those highlighting scientific revolutions) on the other?
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> (3) What is the practical value of scientific innovations? And what connects new technologies emerging from science, with innovative theories, methods, instruments of research itself? How might an innovation framework improve science communication and education?

Thomas Sturm's contribution starts with a conceptual explication of innovation in science itself, as opposed to technological or societal innovations made possible through scientific knowledge. When research is innovative, novel and useful elements of investigation (e.g., a new theory or method or instrument, or several of them in conjunction) begin to spread over a scientific community. Innovation is located between the original invention of a new element of research and its complete dissemination over a community of researchers. (If complete dissemination is achieved, then the invention ceases to be innovative.) Innovation is thus typically a *process*, and since it involves the idea of useful changes of research practices, it is goal-directed and thus requires at least a minimal use of (instrumental) rationality. Therefore, it is neither due to blind chance nor to necessity, and cannot be explained in purely biological or simple naturalistic terms. However, this account leads into a tension between two claims: (1) scientific innovation can be explained rationally; (2) no existing account of rationality explains scientific innovation. Sturm argues that the two most prominent current theories of rationality, the "standard" and "bounded" theories of rationality, cannot deliver such an explanation. A better historical understanding of scientific rationality is required to give proper explanations of scientific innovations *qua* innovations.

In contrast to Sturm, Sergio Martínez defends an evolutionary approach to innovation. He discusses the famous nineteenth-century thesis of continuity, according to which tools and theories of biology should be applied to the social sciences as well. The continuity thesis attracted much criticism in the twentieth century, so that a deeper distinction between the biological and the social sciences appeared acceptable again. However, recent advances in biology suggest a way in which a version of the continuity thesis can be defended. Martínez claims that this opens up new ways of explaining innovations that occur in the social sciences: key kinds of innovation can be explained in terms of the evolution of robust complex systems, interpreted as processes of path creation.

In his contribution, Thomas Nickles addresses issues of scientific progress via an innovation framework that largely bypasses the seemingly stalled debate between strong realists and antirealists. He draws implications from a simple "crowbar" model of methods (research tools). What is important to scientific advance and science policy is not just innovation simpliciter but *rate* of innovation. He defends the view that there is a long-term tradeoff between innovation rates of and degrees of strong scientific realism, a position popular in philosophy of science today as well as among the foundationist epistemological views common in early modern science. Historically, liberalizing methodology has been necessary to open up new theoretical and practical domains, oftentimes at the price of giving up realism about newly emerging theories. One attempt by some realists to avoid paying this price is the so-called "tools-to-theories heuristic", described and evaluated by Gigerenzer and colleagues. But this runs afoul of what Nickles calls "the crowbar fallacy." Still, he accepts that the crowbar model can sometimes be compatible with a moderate, nonrepresentational realism.

Anna Estany and David Casacuberta's contribution addresses another methodological issue concerning scientific innovation. By relating the study of innovation and invention processes to the debate over the theoretical and the experimental traditions in science, they cross the boundary between non-applied or purely theoretical approaches in philosophy of science and the philosophy of technology and applied science. An important example is that of "machine learning"—the branch of computational algorithms designed to simulate, or supersede, human intelligence by learning from the environment. Machine learning is eminently theoretical—in substance it is applied mathematics—but it also possesses numerous features that make it similar to an experimental discipline. In such a science, there is always mutual dependence on theory and experimentation. Importantly, that dependence can also be applied to the processes of innovation and invention.

Finally, Charles Lenay's contribution offers a close case study of the relation between technological innovation and scientific innovation. He considers research in human science, namely, a series of innovations on sensory substitution or perceptual supplementation, especially various devices aiding or replacing the sense of touch that allow for spatial perception, pattern recognition or recognition of others. Interestingly, the devices that were initially developed for the purposes of performing experiments thereafter contributed both to new scientific inventions and to developments with practical and social uses. As Lenay shows, research on the technical constitution of cognitive and perceptual activities can thus result in a process of iterated technological innovation, with the tools presented at each stage preparing the following stages by means of an interpretative framework inherent in those tools.

In sum, the various contributions reveal the enormous complexity and fruitfulness of the topics of scientific innovation, innovation by means of science, and their intricate interactions. We hope to inspire novel studies in this area, and also to encourage new reflection on the basis, the legitimacy, and the usefulness of talk of innovation when it comes to science – both for research and its applications, but also for science policy.

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