Studies in Applied Philosophy, Epistemology and Rational Ethics

Volume 41

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David Danks · Emiliano Ippoliti
Editors

Building Theories

Heuristics and Hypotheses in Sciences

Springer

Editors
David Danks
Department of Philosophy
Carnegie Mellon University
Pittsburgh, PA
USA

Emiliano Ippoliti
Dipartimento di Filosofia
Sapienza University of Rome
Rome
Italy

ISSN 2192-6255 ISSN 2192-6263 (electronic)
Studies in Applied Philosophy, Epistemology and Rational Ethics
ISBN 978-3-319-72786-8 ISBN 978-3-319-72787-5 (eBook)
https://doi.org/10.1007/978-3-319-72787-5

Library of Congress Control Number: 2017962552

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The development of rich, subtle, powerful theories of the world is a signature aspect of the sciences. We do not, in the sciences, simply measure and catalog the world, but rather aim to develop more systematic pictures of parts of the world around us. As one might expect, there are corresponding traditions in the philosophy, history, sociology, and psychology of science whose focus has been, at least nominally, the construction and emergence of scientific theories. At the same time, these traditions have, in many cases, been somewhat disconnected from one another, and from much actual scientific practice. For example, a significant part of the philosophy of science tradition starts with Hans Reichenbach and Karl Popper's sharp division between the "context of discovery"—the conditions and processes in which scientists come up with new theories—and the "context of justification"—the methods that scientists do and should use to evaluate those theories, and then focuses almost exclusively on the latter context. Research in this area of philosophy of science has led to tremendous advances in our understanding of the diverse ways in which scientists integrate information from many sources to evaluate the plausibility of scientific theories, or to determine previously unrecognized limitations of those theories. However, it has provided little-to-no insight into the origins or generation processes of the theories that are the target of scientists' justificatory practices.

More generally, there has been relatively little research on the construction and development of novel theories, and the continual rethinking of old theories. Instead, work on the nature and development of science has focused primarily on experimental and data collection practices, as well as methods for theory confirmation and justification. These are clearly important aspects of the development of scientific knowledge and understanding, but they are equally clearly not the whole of science. Moreover, this prior work has largely and uncritically accepted the orthodox view that the scientific process can be divided into four, logically and temporally distinct stages: (1) generation of new hypotheses; (2) collection of relevant data; (3) justification of possible theories; and (4) selection from among equally confirmed theories. While these are all important aspects of scientific practice, the assumption that they can be cleanly separated—conceptually, logically, or temporally—is a substantive one that is not necessarily borne out by close examination of actual scientific practice. Of course, we inevitably must delimit the scope of our investigations, but focusing on just one of these four aspects arguably threatens to provide a misleading understanding of the sciences.

The papers in this volume start to fill these lacunae in our understanding of the development of novel scientific theories and the adjustment of previous theories; in short, they give us a better picture of how and why scientific theories get built. They spring from a conference at Sapienza University of Rome in June 2016, and represent a number of different perspectives on the nature and rationality of theory construction. They address issues such as the role of problem-solving and heuristic reasoning in theory building; how inferences and models shape the pursuit of scientific knowledge; the relation between problem-solving and scientific discovery; the relative values of the syntactic, semantic, and pragmatic view of theories in understanding theory construction; and the relation between ampliative inferences, heuristic reasoning, and models as a means for building new theories and knowledge. These individual investigations all involve close examination of case studies in multiple scientific fields, including logic, mathematics, physics, biology, and psychology, and each provides insight into a particular aspect of theory construction. Moreover, although each chapter stands on its own, there are consistent themes that emerge across the chapters.

First, we find numerous rejections of the Reichenbachian-Popperian distinction between the contexts and discovery and justification (e.g., the chapters by Gillies, Nickles, Ippoliti, Cellucci, and Sterpetti). These chapters each argue, in their own ways, against a sharp distinction between the construction and evaluation of a particular scientific theory. Instead, they examine the myriad ways in which scientists can, and should, use evaluative or justificatory information and processes to develop novel scientific theories, or adjust the ones that we already have. Second, and relatedly, multiple chapters provide models of scientific discovery and theory building that fall within a middle ground between deductive logic and unjustified guesswork (Morrison, Nickles, Ippoliti, Danks, Darden, Cellucci, Sterpetti, Magnani, and Gillies). Novel theories almost never arise through logical reasoning, and there are typically many logically possible ways to revise our theories in light of conflicting data. These absences of logical guarantees have sometimes been taken to mean that no rational defenses can be given for theory building practices, and so they are tantamount to lucky guesses (perhaps glossed as "scientific insight" or "inspiration"). In contrast, a consistent theme throughout this volume is that theory building is guided by defensible principles and practices that do not guarantee success, but are also not completely arbitrary.

Third, across many chapters, there is widespread use of case studies to both guide and evaluate accounts of theory building (Gillies, Morrison, Nickles, Danks, Darden, Ippoliti, Ulazia, and Longo & Perret).[1] Many investigations of aspects of scientific theories have proceeded from the armchair: the investigator considers

[1] Some authors thus practice what they preach, as they blur the line between theory construction and theory evaluation, though in this case, for philosophical theories rather than scientific ones.

what seems plausible about the science, or evaluates matters entirely based on the final, published scientific record. In contrast, these authors examine the details of particular scientific case studies, both large and small. Importantly, they do not thereby fall into the trap of merely reporting on the science; rather, the particular details provide evidence for rich models of theory construction. Fourth, and more specifically, several chapters emphasize the importance of psychological processes in understanding the ways in which scientists develop and adjust theories (Nickles, Ippoliti, Ugaglia, Ulazia, and Longo & Perret). These psychological models of theory building are partly inspired by the case studies, but are equally informed by relevant cognitive science; they are not simple applications of naïve folk psychology. Moreover, these chapters highlight the focus in much of this volume on both normative and descriptive aspects. Psychological processes are not employed solely to provide descriptive models of how scientific theories are actually built, but also to give a principled basis for evaluation of the rationality (or not) of theory construction processes.

Theory building is a critical aspect of the scientific enterprise, but there have been only sporadic attempts to develop coherent pictures of the relevant processes and practices. The chapters in this volume aim to provide answers to long-standing questions about the possibility of a unified conceptual framework for building theories and formulating hypotheses, as well as detailed examinations of the key features of theory construction. The diverse perspectives, disciplines, and backgrounds represented by the chapters collectively shed significant light on previously under-explored aspects of these processes. We thank the authors for their valuable contributions, and Springer for valuable editorial assistance. The two editors contributed equally to this volume; our names are simply listed in alphabetical order.

Pittsburgh, USA David Danks
Rome, Italy Emiliano Ippoliti

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