

Friedrich Steinle. *Exploratory Experiments: Ampère, Faraday, and the Origins of Electrodynamics.* Pittsburgh: University of Pittsburgh Press, 2016. 544 pp. \$65.00, cloth, ISBN 978-0-8229-4450-8.

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Recent historical focus on research practice in the sciences has brought into relief the complexities involved in experimental work. In the last thirty years Ian Hacking, Andrew Pickering, Nancy Cartwright, Peter Galison, and Alan Franklin, among others, have gradually deconstructed assumptions regarding the primacy of theoretical work through detailed case studies of experimentation. Armed with new philosophical distinctions in types of knowledge (other than those associated with higher level scientific theory), they have constructed historical narratives in which the role of experiment is not exclusively confined to testing theory.

Friedrich Steinle has situated his *Exploratory Experiment: Ampère, Faraday, and the Origins of Electrodynamics*, originally published in German in 2005, firmly within this context of what has been coined “New Experimentalism.” English readers can now appreciate Steinle’s philosophical and historical insights as well as a wealth of freshly uncovered archival material thanks to an excellent translation by Alex Levine. Philosophically, Steinle’s primary contribution to New Experimentalism is his refinement of the book’s titular concept of “exploratory experimentation.” This unconstrained species of experimentation is concerned with uncovering relations and dependencies between experimental parameters even

when the language and concepts necessary to describe these relations are lacking. Particularly (although not exclusively) for disciplines in their infancy, exploratory experimentation can be a powerful tool of both discovery and organization. In its most striking examples, a program of exploratory experimentation is nearly a complete reversal of the traditional theory-led picture. In such instances, experiments establish conceptual hierarchies which come to describe and order phenomena under investigation.

The historical case studies in *Exploratory Experiments* draw on the electromagnetic researches of two of the titans of nineteenth-century experimental physics. Focusing on the work of Andre-Marie Ampère (1775-1836) and Michael Faraday (1791-1867), specifically their work immediately following up on Hans Christian Ørsted’s 1820 discovery of electromagnetism, Steinle illustrates his philosophical point through close attention to their experimental practice. Given the status of Ampère and Faraday, *Exploratory Experiments* provides an excellent reference for anyone interested in the history of experimental practice and European scientific cultures in the burgeoning field of electromagnetism.

The first chapter sets up the experimental and theoretical context across Europe just before Ørsted’s discovery, the spread of voltaic piles and

experimental proficiency with them, as well as the stranglehold of Laplacian physics in France. What were once wildly successful elements of the Laplacian program—its insistence on quantification and its conceptual commitments to microscopic action-at-a-distance—had become constraints on electromagnetic research. In the second chapter Steinle uses this now established context to explain the rapid acceptance of Ørsted's discovery across a variety of European scientific cultures. Critically, this chapter establishes the motivating question for the two that follow: namely, how did Ampère achieve such rapid successes in electromagnetism despite having nearly no experience with electricity, magnetism, or even experimental physics?

Steinle's most novel historical discoveries appear in chapter 3, which contains an incredibly detailed account of the first three weeks of Ampère's experimental program in electromagnetism. Steinle argues that it was during this initial period that Ampère rapidly constructed many of the basic electromagnetic concepts that became central to his work and that he did so through a process of experimentation largely unconstrained by theory. This new narrative is made possible by Steinle's recently discovered documents that are provided in full in two appendices. These are accompanied by copious notes and explanations revealing the complexities involved in reconstructing lost lectures from textual fragments scattered across the Académie des Sciences' Ampère archives.

Chapter 4 examines Ampère's work in the remaining months of 1820 and in January 1821, his move away from the sort of exploratory work described in the preceding chapter, and his new concern with his self-presentation as a Parisian researcher. It is his carefully curated self-presentation which has most blocked the period of exploratory experimentation from prior historical notice (p. 198).

Steinle's fifth and sixth chapters on the scientific culture of London circa 1820 and Faraday's experimental work in 1821 lack the historical drama that surrounds the newly revealed Ampère documents, but he still provides a unique take on the great British experimentalist's work. Faraday's candid laboratory notes are well known and combed through, making the sort of historical discoveries Steinle has unearthed in the case of Ampère unlikely. However, Steinle's study is notable for its insights into Faraday's work after his discovery of electromagnetic rotation and in particular, his use of it as a simplifying concept. Chapter 6 closes with a comparison of Ampère and Faraday's exploratory methods and goals and offers some cultural explanations for their differences.

The concluding chapter of *Exploratory Experiments* refines the concept of exploratory experimentation, situating it in the above-mentioned New Experimentalist literature. Exploratory experimentation may be free of a rigid theoretical context, but it is nonetheless a systematic method of reducing complicated phenomena to simple cases and developing accompanying conceptual representations.

Historians of this period will no doubt be attracted to the painstakingly reconstructed documents generously provided in the appendices, as well as the narrative of Ampère's first efforts in electromagnetism molded out of them. The included diagrams of experimental apparatuses and numerous helpful tables are also welcome additions. Yet they may also find Steinle's criticism of the existing historiography uncharitable. Steinle repeatedly argues that the current literature on Ampère is not just lacking, but that it has been incorrectly reported (pp. 11, 82-84, 121-123, 181). As James Hofmann has shown, Steinle's claim to have corrected historical "missteps" is overselling the account provided in *Exploratory Experiments* (p. 84).[1] Nevertheless, Steinle has certainly filled in our understanding of Ampère's rapid rise in electromagnetism. Illustrating Ampère's ex-

ploratory approach does more explanatory work than simply disassociating him from the Laplacean school.

To a lesser extent this problem also exists in Steinle's account of Faraday. At the conclusion of his fifth chapter, Steinle criticizes L. Pearce Williams' discussion of Faraday's "Historical Sketch of Electro-Magnetism" for "not pay[ing] attention to the autonomy of Faraday's judgement, his development of new means of representation, and the central role of Faraday's own experiments" (p. 225). While the pages Steinle cites in support of this claim are nowhere near as expansive as his own discussion, the suggestion that Williams completely ignored these aspects of the "Historical Sketch" is directly contradicted by very same cited pages.[2] Once again, Steinle has genuinely extended efforts by Williams, David Gooding, and other historians of Faraday through his account of Faraday's conceptual application of electromagnetic rotation; however, at least in the case of Williams, Steinle has oversold his study's novelty. Thus, while Steinle's claims to have entirely upended Ampère and Faraday scholarship are an overreach, *Exploratory Experiments* is unquestionably an enormous contribution to these fields.

Those working on the history of electromagnetism in the second half of the nineteenth century would also do well to read *Exploratory Experiments*. During this period, fundamental electromagnetic concepts took on commanding roles in the construction of electromagnetic theories, namely as elements in analogical relations. Fundamental electromagnetic concepts were linked by analogies to "simpler" mechanical concepts and corresponding relations and concepts were exported via these analogies from mechanics to electromagnetism. For those seeking to investigate the analogical relations that underpin, for example, many of James Clerk Maxwell's electromagnetic theories, the development of these analogically linked concepts is of key importance. *Ex-*

ploratory Experiments has illustrated the origins of certain basic electromagnetic concepts, but longer histories of these concepts will illuminate their evolution and the contingent nature of the analogies and theories of which they are a part. A more complete understanding of how these concepts were constructed and came to be understood can only enrich our own understanding of the theories built from them.

Notes

[1]. James R. Hofmann, review of *Exploratory Experiments: Ampère, Faraday, and the Origins of Electrodynamics*, by Friedrich Steinle, trans. Alex Levine, *Physics in Perspective* (September 2017): 307-318.

[2]. L. Pearce Williams, *Michael Faraday: A Biography* (New York: Basic Books, 1965), 153-156.

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