Studies in History and Philosophy of Science xxx (2017) 1–7

Contents lists available at ScienceDirect

Studies in History and Philosophy of Science

journal homepage: www.elsevier.com/ locate/shpsa

The making of measurement: Editors' introduction

Keywords:
Measurement
Metrology
Models
Kuhn

A B S T R A C T

This special issue consists of selected papers arising from the interdisciplinary conference "The Making of Measurement" held at the University of Cambridge on 23–24 July 2015. In this introduction, we seek ways to further productive interactions among historical, philosophical, and sociological approaches to the study of measurement without attempting to lay out a prescriptive program for a field of "measurement studies." We ask where science studies has led us, and answer: from the function to the making of measurement. We discuss whether there is anything privileged or exemplary about physical measurement, and alight upon models and metrology, two particular focuses of enquiry that emerge from our selection of papers. Those papers with a historical dimension complement an already well-developed body of historiography applied to measurement and metrology.

In the scholarly and the popular imagination alike, heroes of science are often great theorists, sometimes great experimenters, but seldom great measurers.[1] However, in recent years historians, philosophers and sociologists of science have begun to take measurement seriously as a quasi-autonomous activity, historically situated with its own cultures and practices. A growing scholarly literature has identified the conceptual richness and inherent creativity of measurement by exposing the complexity behind familiar notions such as error, uncertainty, accuracy and precision. This moment in history is also witnessing dramatic changes in the metric system. We think that the time is ripe for the development of a systematic approach to the humanistic study of measurement.

This special issue of *Studies in History and Philosophy of Science* arises from the conference "The Making of Measurement" held at the University of Cambridge on 23–24 July 2015. Our conference was inspired by a previous one, "Dimensions of Measurement," held at Bielefeld University in Germany in 2013, which resulted in two edited volumes, one on the epistemology of measurement and the other on standardization (Mößner & Nordmann, 2017; Schlaudt & Huber, 2016 [2015]).[2] Like the Bielefeld meeting, ours was consciously interdisciplinary, and sought to generate a synthetic perspective on the nature, function and history of measurement. Until recently, historical, philosophical, and sociological studies of measurement have developed quite separately from each other. Even within each of these fields, various different schools of thought have co-existed. Inevitably, tensions have arisen between diverse methodologies, particularly with respect to whether measurement outcomes reflect facts about nature, or about human tools and concepts, or both. Indeed, the volume on standardization that emerged from Bielefeld sought consciously to reconcile such tensions for this one crucial aspect of measurement (Huber & Schlaudt, 2016 [2015]). Here we seek ways of furthering productive interactions on a broader front without attempting to lay out a prescriptive program for a field of "measurement studies."

1. Measurement: trends in science studies since Kuhn

Current interest in measurement finds a precedent and a parallel in the so-called "experimental turn" in science studies in the 1980s, which challenged the traditional primacy of theory in science, and more specifically the philosophical and cultural prejudice that "experimenters sit around waiting to be told to test, confirm, or refute theories." (Hacking, 1983, p. 239) Philosophers of science including Ian Hacking and Nancy Cartwright (1983) argued that the reality of experimental effects and the truth of phenomenological laws could be established independently of high-level theories. Historians of science (e.g. Jed Buchwald, Peter Galison, Allan Franklin, Steven Shapin and Simon Schaffer) provided fine-grained accounts of experimental practices that bore out these philosophical instincts. We are now accustomed to attributing multiple aims and functions to theory, experimentation, and instrumentation within science and treating them quasi-independently (e.g. Galison, 1997, ch. 9). Within the study of these traditions, it

[1] The heroic "measurer" who most readily springs to mind is Albert Michelson, who won the Nobel Prize in 1907 for "his optical precision instruments and the spectroscopic and metrological investigations carried out with their aid." (Hasselberg, 1907) But his popular fame is premised upon the myth that his work (with Edward Morley) played the theoretical role of disproving the existence of the ether, thereby precipitating the relativity revolution. For a historical account of Michelson's instrumental and experimental projects on his own terms, see Staley (2009, ch. 2). Kuhn (2012 [1962], p. 26) names Tycho Brahe and Ernest Lawrence as two others who achieved enduring reputations based upon measurement.

[2] As we go to press we note the organisation of a third conference in this series, "Measurement at the Crossroads," to be held in Paris in June 2018.

https://doi.org/10.1016/j.shpsa.2017.10.001

has also become the norm to examine specific practices from a variety of viewpoints (epistemological, social, material, and so on).

This special issue advances the idea that measurement deserves a special focus in the study of science and technology, independently of the study of experimentation. While the two topics are closely related—many experiments involve measurement—they are also clearly distinct. Some scientific experiments are qualitative, and do not involve measurement in any commonly accepted sense of the term. Many measurements, in turn, are performed in contexts that have little to do with experimentation: from the weight of commercial goods to the concentration of pollutants in water, and from a country's gross domestic product to a patient's blood pressure, the scope of measurement extends far beyond experimental science. From a methodological perspective, too, measurement involves a host of unique tasks, such as scale construction, uncertainty evaluation and standardization, that are in general different from those of experimental design and involve special conceptual challenges. Finally, from a sociological perspective, the institutions that develop and regulate measuring procedures are often distinct from the institutions that use these procedures to design and run experiments.

It is instructive to reflect upon the Bielefeld and Cambridge projects in their longer-term methodological context. Half a century ago, a joint committee on the history of science set up by the Social Science Research Council and the National Research Council in the United States organized two conferences, the second of which "dealt with a composite analysis of the introduction and development of quantitative techniques in the natural and social sciences." (Woolf, 1961, p. 3) This led to the publication in 1961 of a collection edited by Harry Woolf, the editor of the History of Science Society's journal *Isis*, entitled *Quantification: A History of the Meaning of Measurement in the Natural and Social Sciences.* The principal papers basically broke along scientific disciplinary lines: physics, chemistry, biology, medical science, psychology, economics, and sociology. Yet there was an underlying presumption of unity: of the operational concept of measurement adopted between disciplines, of the practices of measurement within each of them, and of the trajectory of all sciences towards the refinement of quantitative capabilities.[3] These kinds of unity, whether between or within disciplines, are scarcely possible to maintain when confronted with more recent case studies in the history of science presented here and elsewhere.

Among the essays in Woolf's volume was "The Function of Measurement in Modern Physical Science" by Thomas Kuhn, who would go on to publish *The Structure of Scientific Revolutions* just one year later.[4] It is important to note that Kuhn mapped his division of "normal" and "extraordinary/revolutionary" science onto "normal" and "extraordinary" functions of measurement.[5] Indeed, "The Function of Measurement" basically used measurement as an axis for orienting the principal ideas and dichotomies that later appeared in *Structure* (cf. Hacking, 1983, pp. 242–5). In the excitement that followed the publication of *Structure*, philosophers and even many historians tended to ignore the importance of normal science while they argued about revolutions, incommensurability, realism, relativism, and objectivity. This has meant that measurement became a topic of interest only in exceptional cases, namely when it generated anomaly.

It was not Kuhn's intention, however, to marginalize normal science and hence the central role of the "overwhelmingly most common scientific function" of measurement, namely increasing the scope and accuracy of a paradigm (Kuhn, 1977 [1961], p. 188). He argued that "the sort of work that most physical scientists do most of the time *insofar as their work is quantitative*" aimed "on the one hand, to improve the measure of 'reasonable agreement' characteristic of the theory in a given application, and, on the other, to open up new areas of application and establish new measures of 'reasonable agreement' applicable to them." (Kuhn, 1977 [1961], p. 192) In *Structure*, Kuhn stressed even more strongly that this process presented "a constant challenge to the skill and imagination of the experimentalist and observer." Special apparatus devised for the purpose of bringing "nature and theory into closer and closer agreement" bore witness to "immense effort and ingenuity." (Kuhn, 2012 [1962], p. 27)[6]

In the spirit of Kuhn's original appreciation of normal science, interest has recently shifted decidedly towards concrete practices of measurement, hence the title of our conference. Recent moves to provide an "epistemology of measurement" have widened enquiry to include calibration, imaging technologies, and instrument design and operation, in a great variety of settings (Mößner & Nordmann, 2017). Consonant with the perspective of variegated traditions or cultures of theoretical and experimental practice, all measurements have become candidates for study independently of their relationship to theory. We now know that even the most apparently canonical measurements that Kuhn (1977 [1961], p. 188) thought were "widely understood"—boiling points, electrical contact potentials, and the acidity of solutions, to select from Kuhn's (2012 [1962], pp. 25–6) list—can raise deep philosophical issues of justification, upon close investigation (Ruthenberg and Chang, this issue; Chang, 2004, pp. 8–56).[7] Kuhn did highlight the prior qualitative groundwork necessary for quantification, but not the conceptual or material innovation required, for instance, in the historical construction and operationalization of measurement scales. The making of measurement has taken place in full interaction with creative developments in other experimental and theoretical practices in science and technology.

2. Beyond physics? From physics to metrology

Kuhn observed at the time of *Quantification* that "physical science is so often seen as *the* paradigm of sound knowledge," citing Lord Kelvin's notorious declaration: "When you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind." (quoted in Kuhn, 1977 [1961], p. 178) Kuhn then asked an audience of social scientists whether the Social Science Research Building at the University of Chicago would have been inscribed with these words had they been uttered "not by a physicist, but by a sociologist, political scientist, or economist?" He continued:

> Would terms like "meter reading" and "yardstick" recur so frequently in contemporary discussions of epistemology and

[3] Take the introduction by the statistician Samuel S. Wilks. From his reading of the papers included in the collection, he extracted some common characteristics of measurement. At the top of his list was "measurement must be an operationally definable process." (Wilks, 1961, p. 5) The flexibility of this criterion enabled him to link determinations of the velocity of light with the estimation of unemployment during a given week in the United States.

[4] This paper was reprinted in a later collection of Kuhn's essays, *The Essential Tension* (1977). We quote from that version as it is more readily available.

[5] In discussing the historical and conceptual connections between 'The Function of Measurement' and *Structure*, Marcum (2015), pp. 13–16, 43–51, comes close to this position.

[6] Compare Kuhn, 2012 [1962], ch. 3, "The nature of normal science," with Kuhn, 1977 [1961], pp. 187–192 ("Motives for normal measurement").

[7] Kuhn (2012 [1962], p. 26) again stressed the ingenuity and talent involved in the instrumental implementation of these types of "factual determinations." (p. 25)