Consequences of Standardized Technical Effects for Scientific Advancement

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Over the last 40 years, historians of science have repeatedly produced evidence contradicting the widespread assumption that technology is a product of experimentation and/or theory (Kuhn 1961; Latour 1987; Rabkin 1992; Schaffer 1992; Hankins & Silverman 1999; Baird 2002). Theory and experiment typically advance only within the constraints set by a key technology that is widely available to end users in applied and/or research contexts. Thus, "it is not just a clever historical aphorism, but a general truth, that 'thermodynamics owes much more to the steam engine than ever the steam engine owed to thermodynamics'" (Price 1986, p. 240).

The prior existence of the relevant technology comes to bear on theory and experiment again in the common, but mistaken, assumption that measures are made and experimentally compared in order to discover scientific laws. History and the logic of measurement show that measures are rarely made until the relevant law is effectively embodied in an instrument (Kuhn 1961; Michell 1999). This points to the difficulty experienced in metrologically fusing (Schaffer 1992, p. 27; Lapré & van Wassenhove 2002) instrumentalists' often inarticulate, but materially effective, knowledge (know-how) with theoreticians' often immaterial, but well articulated, knowledge (know-why) (Galison 1999; Baird 2002).

Because technology often dictates what, if any, phenomena can be consistently produced, it constrains experimentation and theorizing by focusing attention selectively on reproducible, potentially interpretable effects, even when those effects are not well understood (Ackermann 1985; Daston & Galison 1992; Ihde 1998; Hankins & Silverman 1999; Maasen & Weingart 2001). Criteria for theory choice in this context stem from competing explanatory frameworks' experimental capacities to facilitate instrument improvements, prediction of experimental results, and gains in the efficiency with which a phenomenon is produced.

In this context, the relatively recent introduction of measurement models requiring additive, invariant parameterizations (Rasch 1960) provokes speculation as to the effect on the human sciences that might be wrought by the widespread availability of consistently reproducible effects expressed in common quantitative languages. Paraphrasing Price's comment on steam engines and thermodynamics, might it one day be said that as yet unforeseeable advances in reading theory will owe far more to the Lexile analyzer (Burdick & Stenner 1996) than ever the Lexile analyzer owed reading theory?

Kuhn (1961) speculated that the second scientific revolution of the mid-nineteenth century followed in large part from the full mathematization of physics, i.e., the emergence of metrology as a professional discipline focused on providing universally accessible uniform units of measurement (Roche 1998). Might a similar revolution and new advances in the human sciences follow from the introduction of rigorously mathematical uniform measures? This presentation will explore these and related issues, focusing on the primary difference between the case of 19th century physics and today's human sciences: the awareness, widespread among scientists in the 1800s and virtually nonexistent in today's human sciences, that universal uniform metrics for the variables of interest are of great human, scientific, and economic value. Possibilities for expanding such an awareness in the human sciences today are explored.

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Recent historical studies (Schaffer 1992; Heilbron 1993; Roche 1998; Alder 2002) substantiate Kuhn's (1961) speculation that the second scientific revolution of the mid-nineteenth century followed in large part from the emergence of metrology as a professional discipline focused on providing universally accessible uniform units of measurement.

These historical considerations raise a vital question. Measurement technologies capable of supporting the calibration of additive units that remain invariant over instruments and samples (Rasch 1960) have been introduced relatively recently in the human sciences. The invariances produced appear 1) very similar to those produced in the natural sciences (Fisher 1997) and 2) based in the same mathematical metaphysics as that informing the natural sciences (Fisher 2003). Might then it be possible that the human sciences are on the cusp of a revolution analogous to that of nineteenth century physics? Other factors involved in answering this question, such as the professional status of the field, the enculturation of students, and the scale of the relevant enterprises, will be explored en route to describing the structure of circumstances that might be capable of supporting the kind of theoretical consensus and research productivity that came to characterize, for instance, work in electrical resistance through the early 1880s (Schaffer 1992). The primary difference found between the two is crucial: the awareness, widespread among scientists in the 1800s and virtually nonexistent today, that universal uniform metrics for the variables of interest are of great human, scientific, and economic value. Possibilities for expanding such an awareness in the human sciences today are explored.

Fusing instrumental know-how with theoretical know-why on a broad scale has three essential requirements. The emergence of any successful new natural science has historically been marked by an expanding technical network employing 1) a reference standard metric that provides all end users with a common language, 2) social and economic connections reinforced at conferences, meetings, and via employment opportunities, and 3) resources for enculturating new members, such as textbooks and degree programs (Latour 1987; Schaffer 1992).

In the creative dynamics of scientific instrument making, as in the making of art, the combination of inspiration and perspiration can sometimes result in cultural gifts of the first order. Some of these superlative gifts, no matter how well executed, are unable to negotiate the conflict between commodity and gift economics characteristic of the scientific marketplace (Hagstrom 1965; Baird 1997), and so remain unknown, lost to the audiences they deserve, and unable to render their potential effects historically. Value is not an intrinsic characteristic of the gift; rather, value is ascribed as a function of interests. If interests are not cultivated via common languages, socio-economic relations, and recruitment, gifts of even the greatest potential value may die with their creators. On the other hand, who has not seen mediocrity disproportionately rewarded merely as a result of intensive marketing?

With the relatively recent introduction of mathematically rigorous measurement models, the human sciences have acquired the technical capacity needed for expressing measures in units that are independent of the particular instrument used, the sample measured, the researcher measuring, time, and space. This ability to quantify consistently reproducible effects opens up a world of possibilities for the calibration of reference standards

The first is readily available, reliable technology for producing experimentally variable unit amounts of an effect, with those units expressed in a common language for expressing amounts of that variation.

The history of science shows that technology has a long record of facilitating:

- the quantification of variables;
- common languages for referring to specific amounts of various variables;
- the formation of the social networks through which variables are produced and managed for economic, social, and political gains;
- the routine observation, manipulation, and comparison of consistent amounts of variables; and
- the emergence of theories and experiments relevant to the efficient production of the variable.

Examples of each of these effects of technology are provided from the history of science.

Quantification must be understood in the fully mathematical sense of commanding a comprehensive grasp of the real root of mathematical thinking. Far from being simply a means of producing numbers, to be useful, quantification has to result in qualitatively transparent figure-meaning relations at any point of use for any one of every different kind of user. Connections between numbers and unit amounts of the variable must remain constant across samples, instruments, time, space, and measurers. Quantification that does not support invariant linear comparisons expressed in a uniform metric available universally to all end users at the point of need is inadequate and incomplete. Such standardization is widely respected in the natural sciences but is virtually unknown in the human sciences, largely due to untested hypotheses and unexamined prejudices concerning the viability of universal uniform measures for the variables measured via tests, surveys, and performance assessments.

Quantity is an effective medium for science to the extent that it comprises an instance of the kind of common language necessary for distributed, collective thinking; for widespread agreement on what makes research results compelling; and for the formation of social capital's group-level effects.