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Measurement in interdisciplinary research: The contributions of widely-defined measurement and portfolio representations

Hilde Tobi *

Research Methodology group, Wageningen University, The Netherlands

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ABSTRACT

An area of application of measurement with increasing relevance to science and society is interdisciplinary research. Measurement in interdisciplinary research poses new challenges to the theory of measurement, especially when scientists with different disciplinary cultures collaborate. A common framework that allows and invites communication about the process of measurement, including the content and form of the entities under study, is needed. The present paper aims to contribute to such a framework by operational widely-defined measurement and how the portfolio representation of measurement fits within operational widely-defined measurement and supports measurement of the kind of complex attributes often investigated in interdisciplinary research.

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1. Introduction

Terms and concepts that work across disciplines are essential for the study of the intrinsically multidisciplinary phenomena [1,2]. When discussing the necessary basic concepts and terms in measurement, the multidisciplinary background of the participants in the European 'Measuring the Impossible' Network (MINET) showed explicitly in the distinction between 'measuring man' and 'man as measurement instrument' [3]. While willing and able to build on the International Vocabulary of Metrology [4], the MINET had to agree to disagree on some basic terminology when creating their glossary of perceptive measurement [3,5]. This is an illustration of how cross-disciplinary concepts and terms in measurement can only prevent misunderstandings of each other's jargon when they are understood in the same way and when all disciplines involved feel free and welcome to contribute.

Many current challenges, e.g. energy, water, and urbanization, involve the interaction between humans and their environment. Study of these challenges requires collaboration between scientists trained in different disciplines (e.g. chemistry or biology in the natural sciences, sociology or psychology in the social sciences). More precisely, interdisciplinary research is [6, p. 341]: "any study or group of studies undertaken by scholars from two or more distinct scientific disciplines. The research is based upon a conceptual model that links or integrates theoretical frameworks from those disciplines, uses study design and methodology that is not limited to any one field, and requires the use of perspectives and skills of the involved disciplines throughout multiple phases of the research process".

Scientific disciplines are often classified into the natural sciences, the social sciences and the humanities and they are considered to have distinct scientific cultures [e.g. 7]. For interdisciplinary research, teams that involve both natural and social scientists, the cultural commonalities may be few and obscure. A review of the literature on collaboration between natural and social scientists identified four types of difference that create barriers and opportunities between current mono-disciplinary sciences: the paradigms or more precisely epistemologies, skills and competences of the scientists involved, institutional context of the research, and organization of collaborations [8]. Shared

* Address: Research Methodology group, Bode 68, Hollandseweg 1, 6706 KN Wageningen, The Netherlands. Tel.: +31 (0) 317 485 946x702.
E-mail address: hilde.tobi@wur.nl

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goals in research can help overcome paradigm barriers. Interest, willingness to get involved and to adapt, modesty about the remit of their own disciplines and mutual respect are all reported factors in the effective collaboration involving social and natural scientists [8]. These, however, are not enough. Effective collaboration requires a common lexicon of measurement.

Measurement is not only a process within interdisciplinary research, but also an interdisciplinary subject of thought. Measurement theory in interdisciplinary research must facilitate discussion of the construct (the theoretical concept), the entity (the phenomenon, the body or material under study [5]), the content (the substance [5]) and the form (the accidence [5]) of the entity before scientists can move on to choosing a measuring system and assigning values. These discussions are within 'the process of measurement' as defined in the present paper. The next section introduces operational widely-defined measurement to support discussions on the process of measurement in interdisciplinary research. The third section of this paper elaborates on the portfolio representation of measurement recently introduced in this journal [9] and shows its relevance to measurement in interdisciplinary research. The paper concludes with a summary and a list of issues in measurement in interdisciplinary research that warrant further thought and investigation.

2. Operational widely-defined measurement for interdisciplinary research

The concept of measurement and measurement theory is a cornerstone in all empirical research, single disciplinary and interdisciplinary. The basic paradigm for measurement stems from the experimental sciences, but measurement is also generally applied in the social and behavioral sciences [2]. Finkelstein' s wide definition of measurement as [10, p. 268]: "a process of empirical, objective assignment of symbols to attributes of objects and events of the real world, in such a way as to represent them, or to describe them" aimed to bridge the gap between measurement in the experimental sciences and measurement in those social sciences that assume the existence of measurable objects and attributes. Because measurement units have mostly been limited to real scalar quantities (e.g. VIM and MINET) it is important to note that here "symbols" may be understood to refer to all scales of measurement from nominal to ratio, and that words used as labels may be regarded as symbols too. When we further recognize as measurement evaluations relevant to objectives for which it is impossible to elicit objective values that are inherent properties of the measured things [11], large domains in the social sciences are covered under this "softer" metrology [9].

Operational widely-defined measurement relies on theory to inform scientists as to how the content and form of the entity (the phenomenon, body or material under study) needs to be measured. In the natural sciences, theory has taken the form of accepted physical laws which connect indirect measures with direct ones. Consequently, operational widely-defined measurement includes both the direct (fundamental) measurement and the derived (indirect) measurement commonly used in the natural sciences. In the social sciences, due to the combination of lack of epistemological consensus [e.g. 12–14] and the nature of the phenomena and objects under study, there is no broadly accepted equivalent to physical laws in the natural sciences. Instead, different and sometimes contradictory theories are used to describe or explain the same phenomenon. In operational widely-defined measurement, the disruptive effect of a lack of an equivalent to physical laws in the social sciences is mitigated by the process of operationalization. Operationalization iteratively decomposes the immeasurable attribute of interest (reflecting content and/or form) into components until measurable characteristics are reached in an explicit and auditable way. In the absence of an equivalent to physical laws, the identification of measurable components in the social sciences requires persuasion as to the credibility of the theory and procedures used in operationalization. Once ideas converge and agreement is reached on the appropriate decomposition of the immeasurable attribute of interest into measurable components, attention is expected to shift to combining components such that that they produce one 'measure value' [1]. Measurement, as an empirical process of operational widely-defined measurement, encompasses the measurement of man and the man as measurement instrument (distinguished by the MINET) as well as the measurement by instruments engineered by humans.

In contrast to some other measurement definitions [e.g. 15], operational widely-defined measurement includes data processing to obtain a symbol for a (usually non-physical) property of the object of interest, under the hypothesis that raw data were obtained. It includes any symbol and not only those denoting real scalars. Operational widely-defined measurement does not imply 'anything goes'. Firstly, operational widely-defined measurement requires an auditable empirical process and, consequently, excludes the thought experiments common in the humanities. Secondly, the scale of measurement dictates the operations allowed on the measurement values [16], meaning that words as measurement unit allow only for distinction and, sometimes, ranking. Observer invariance, instrument invariance, attribute continuity and time continuity, the two invariance and two continuity criteria measurement should satisfy [9], remain meaningful although the mathematical representation for units of nominal scales becomes different. Observer and instrument invariance is reached when the result of the measurement process is not dependent on the observer, the instrument, or specific combinations of the observer and the instrument. As a measurement is better defined and matures from emergence to persuasion, observer and instrument independence is expected to increase [9]. In interdisciplinary research, both the observer and instrument must be explicitly defined as the observer may be (part of) the instrument which makes it more complicated, or even impossible, to distinguish between the two. Also, the scale of measurement may be such that statistical correlation, proposed as a measure of observer and instrument independence by [9], becomes meaningless. The concept of triangulation as understood in qualitative research [e.g. 17,18], may be

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