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Commentary

Demystifying beliefs about the natural sciences in information system

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Introduction

Beliefs about natural science have been influential in information system (IS; Orlikowski and Baroudi, 1991).[1] For example, a belief exists that 'the methods of natural science constitute the only legitimate methods for use in social science' (Evaristo and Karahanna, 1997: 39). These legitimate methods include the use of 'quantitative empirical methodologies—field experiment, survey, and laboratory experiments' (Evaristo and Karahanna, 1997: 39). Understandably, many qualitative IS scholars have reported serious pressure to meet such standards. For example, De Vaujany et al. (2011) asserted that 'in order to survive, the IS field had to draw on a model of research attributed to the natural sciences' (p. 405). Similarly, Lyytinen and King (2004) referred to the 'orthodox' view in IS, according to which the IS 'field's survival depended on . . . drawing on a model of research attributed to the natural sciences' (p. 222).

If quantitative methodologies are the only legitimate scientific methods, then how did those IS scholars who did not use quantitative (e.g. statistical) research methods survive? One strategy was to accept the orthodox position: 'Organizational researchers must try harder to make the study of organizations fit the natural science model, since (according to the positivist approach) this is the only way in which organizational research can become truly scientific' (Lee, 1991: 343). This strategy aimed to show how qualitative studies could meet the alleged natural science beliefs or how '[q]ualitative research is just as able as quantitative research to follow certain fundamental principles of . . . scientific reasoning' (Lee and Hubona, 2009: 237). Furthermore, the strategy led to the development of the 'natural science model of social science' in IS (Lee, 1989; Lee and Hubona, 2009; Ngwenyama and Lee, 1997). This oft-cited model endeavours to reflect 'how research proceeds in physics, biology, and other natural sciences' (Ngwenyama and Lee, 1997: 149). Seminal studies have reported that 'the natural science model of social science' is 'now widely accepted' (Klein and Myers, 1999: 67) and has 'become [the] de facto standard' (Klein and Myers, 1999: 69) for case studies in IS.

Other strategies for justifying qualitative approaches have varied even more. A common tactic has been to make a sharp distinction between the natural sciences and social sciences. The former is sometimes characterized as objective, positivistic, and quantitative, while the latter is regarded as qualitative and interpretive (e.g. Orlikowski and Baroudi, 1991). This tactic does not question the existing natural science beliefs in IS; rather, it attempts to show that these beliefs are unsuitable for qualitative research, or that qualitative research benefits from alternative approaches. For example, Klein and Myers (1999) noted, 'While the conventions for evaluating information systems case studies conducted according to the natural science model of social science are now widely accepted, this is not the case for interpretive field studies' (p. 67).

These developments resulted in natural science methodological beliefs being formulated by various parties: those who view quantitative methods as the methods of natural science, those who advocate the 'natural science model', and those who view natural science beliefs as inappropriate for qualitative (or interpretive) research. A similar trend has continued in design science. For instance, the most frequently cited design-science article in IS separates 'behavioural science' from design science, noting that the former 'has roots in natural science research methods' (Hevner et al., 2004: 76). In IS, certain beliefs are customarily distinguished as belonging to the realm of natural science, with others belonging to social science with such a distinction described as the 'technical-natural science-positivistic paradigm vs social constructivist-social science-interpretive paradigm' (Iivari, 2008: 171).

None of these parties has questioned whether the prevailing beliefs about natural science in IS are supported

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by evidence from the contemporary philosophy of natural science or from the natural science practice. Furthermore, some natural science-based beliefs have become commonly accepted in IS with questionable evidence or without any evidence. For example, the influential natural science model of social science claims to reflect 'how research proceeds in physics, biology, and other natural sciences' (Ngwenyama and Lee, 1997: 149). Regardless of whether the model provides any evidence as to 'how research proceeds in physics, biology, and other natural sciences', it is reported as being 'widely accepted' (Klein and Myers, 1999: 67).

An important task for philosophy of science is a critical analysis of the key concepts used by scientists. Such analysis can make significant contribution to IS by, for example, correcting widely held misunderstandings of some basic philosophy of science concepts (Williams and Tsang, 2015). Given the centrality of natural science beliefs in IS in both past and recent debates (e.g. McBride, 2018a, 2018b), those beliefs merit a critical review. This article contributes to IS research by suggesting corrections to some misinterpretations regarding the philosophy of natural sciences in IS. In the absence of such corrections, many researchers or reviewers may risk setting unrealistic goals for IS research or 'real science' – goals that many natural sciences cannot meet. Moreover, given these problematic natural science beliefs, some IS scholars (who, for example, oppose natural science beliefs) may fail to learn useful lessons from the philosophy of natural sciences. Finally, some IS scholars may risk focusing solely on statistical or mathematical methods, given their misplaced belief that statistical or mathematical methods are the only valid natural science methods.

This study differs from that of Siponen and Tsohou (2018), who question some IS beliefs concerning (logical) positivism. This study does not discuss any positivistic philosophers, but rather questions some IS beliefs regarding the philosophy of natural sciences. Finally, it is worth emphasizing that we are not against quantitative, qualitative, or design-science research approaches, as any of these can produce valuable information in principle: rather, we focus on questionable views about the natural sciences. Problematic natural science beliefs have been cited by some members of the quantitative, qualitative, or design-science communities. Our point is not to ask if any one community is more correct or 'less wrong' than another when it comes to natural science beliefs; rather, we argue that IS scholars should examine the problems and merits of each natural science belief individually. We do this in the course of questioning problematic natural science beliefs, irrespective of whether they are proposed by quantitative, qualitative, or design-science scholars.

Characterizations of natural science in IS

This section reviews and questions some influential IS beliefs about natural sciences, which are simplified herein into three clusters: (1) methodological issues, (2) objective observations and truth, and (3) general laws, deterministic philosophy, and the transferability of the laboratory findings to real settings. This analysis points out some major confusion on some basic scientific concepts. Many natural science conventions in IS, if imposed by scientists, would render fundamental laws of physics or modern biology as rejected or unscientific.

The section on methodological issues first focuses on the qualitative/quantitative distinction and criticizes some of the definitions of qualitative and quantitative research. The discussion then criticizes the tendency to regard quantitative methods as natural science and qualitative methods as social science. Regarding objective observations, some seminal IS articles have taught that natural science–oriented researchers do not intervene in the phenomena they study. A reader of IS literature might learn that scientific philosophy does not include interpretation and judgement and that natural science–oriented researchers can objectively predict or evaluate any phenomenon. In this section, a consultation of the modern philosophy of natural science questions both of these claims. The section on general laws, deterministic philosophy, and transferability of laboratory findings to real settings questions the role of true laws in natural sciences as well as the claim that real sciences require determinism. In addition, the direct transferability of isolated laboratory findings to real settings is questioned. Finally, section 'Discussion' highlights some implications for IS research, and section 'Conclusion' provides a conclusion.

Methodological issues

Quantitative natural science and qualitative social science. Many social-science textbooks claim that qualitative methods belong to the social sciences, while quantitative methods are natural science methods (Denzin and Lincoln, 2008; Hammerslay and Atkinson, 2007; Patton, 2002). For example, Bryman (1984) explained that '[q]uantitative methodology is routinely depicted as an approach to the conduct of social research which implies a natural science . . . approach to social phenomena . . . The survey is typically seen as the preferred instrument within this tradition' (p. 77). A similar narrative is found in IS, with scholars expressing the belief that 'quantitative methods were originally developed in natural sciences to study natural phenomena'[2] and giving survey methods and laboratory experiments as examples of quantitative methods (Myers, 2013: 7). Mingers (2003) summarizes the situation: 'There has been a tendency to link quantitative methods with a natural science (positivist) approach, and qualitative methods with a social science (interpretive) approach' (p. 236).[3]

We do not disagree that qualitative methods are used in social science, or that many 'quantitative research methods were developed in the social sciences' (Myers, 2013: 8). However, whether qualitative investigations also play an important role in some natural sciences must be determined here. Answering this question satisfactorily requires defining what constitutes a qualitative investigation. IS articles typically define qualitative research by listing methods such as interviews, case studies, action research, and observations (e.g. Evaristo and Karahanna, 1997; Klein and Myers, 1999). Although such definitions may suffice for researchers seeking to use qualitative methods, a list of examples does not explain why these methods are qualitative while others are not. Separating qualitative and quantitative methods without providing sufficient definitions for either is philosophically problematic.

To illustrate these problems, the following must be asked: do any qualitative interview papers published in IS refrain from stating the number of interviewees? Qualitative scholars tend to count the number of respondents. However, this action is quantitative in nature. In turn, claiming that survey research is quantitative, or that 'all quantitative scholars emphasize numbers more than anything else' (Myers, 2013: 7), also seems problematic. Survey designers most likely use qualitative judgement in various places. For example, if researchers contextualize survey instruments, then how is this contextualization process quantitative and not qualitative and how can one say that it 'emphasize[s] numbers more than anything else' (Myers, 2013: 7)?

Thus, the qualitative/quantitative dichotomy seems problematic. However, if the dichotomy must be used, then numerous investigative approaches in biology, biochemistry, and chemistry research may not necessarily entail statistical analysis or 'emphasize numbers more than anything else' (Myers, 2013: 7). First, the observation of phenomena plays an important role in basic biological research. The easiest example to understand may be observations using microscope, which can be characterized as qualitative rather than quantitative (in the sense that they can be performed without mathematical proofs or statistical analysis). The wholesale categorization of microscope observations as 'quantitative' is not convincing.

Observation under a microscope is taught in biology and biochemistry, beginning in the first or second year of undergraduate education.[4] Examinations of animal behaviour in biology may also include qualitative observations (without mathematical proofs or statistical analysis). At the same time, many of the natural sciences, including all biological sciences, biochemistry, chemistry, and physics, rarely use surveys.

Walsham (1995a) highlighted tape-recording and note-taking as key methods for interviews. While natural scientists rarely use interviews, note-taking is common among natural scientists. For instance, Lenox (1985) argued that 'the habit of observing and recording should be taught by requiring the student to keep a regular laboratory notebook'. Lenox (1985) observed that '[n]ot only does this require a decision as to what to record, but it forces a student to observe carefully and critically' (p. 283). To summarize, natural scientists do not use only the methods IS sources designate as natural science; for instance, qualitative observations are natural science methods.

Differences between natural science methods and statistical or mathematical methods. A number of influential IS authors have associated statistical methods with scientific or positivist methods that were, in turn, associated with natural science. Perhaps the most frequently cited is the natural science model (Lee and Hubona, 2009; Ngwenyama and Lee, 1997). The natural science model consists of 'mathematical propositions, quantitative data, inferential statistics, and experimental controls' that are 'often associated with natural sciences' (Lee and Hubona, 2009: 238).

Natural scientists can use different statistical or mathematical methods. However, in certain fields, such as biochemistry or biology, such methods may not be among the most commonly used. The more important issue is that identifying statistical and experimental methods with natural science methods pays no attention to the complexity and variety of the methods and research instruments used in different natural sciences. For instance, biochemistry alone contains hundreds of methods that are not best characterized as statistical methods (although the results may be analysed statistically). Such methods have even won Nobel prizes, such as the polymerase chain reaction (PCR). The PCR is not a statistical method, although PCR results can be analysed statistically.

Moreover, natural science research does not have to consist of experiments with a control group and experimental group. For example, 'astronomy . . . can never become an experimental science, since heavenly bodies cannot be shifted' (Stegmüller, 1977: 19). Herschel (1831: 76) long ago made the distinction between experiments and observations. The countless situations in IS research in which experimental research is difficult, if not impossible, can be easily imagined. For example, experimentally examining (in real settings) how different ecommerce initiatives would survive under different economic conditions is difficult, if not impossible.

On statistical research. McBride (2018a) suggested that quantitative research in social sciences 'render[s] colourful phenomenon in black and white' (p. 168), implying that this is not the case in the natural sciences. However, it has been well known since Galileo's 'idealized construct' that a mathematical or statistical treatment often, if not typically, results in natural science models that purposefully misrepresent some part of the phenomenon (McMullin, 1985). Due to such reasons, it has become common to note in the philosophy of science that 'all statistical models include a number of assumptions about the underlying data generating process, sampling, and the observed distributions, that are, strictly speaking, false' (Kuorikoski, 2012: 441). The assumptions in the statistical models may not match the actual phenomena studied and are, in this sense, false. For example, some physicists may assume stability or linearity in order to study certain phenomena mathematically, even though they know that these phenomena do not actually possess these characteristics (McMullin, 1985). As described by Chalmers (1993), 'In order to fit a phenomenon into the mathematical framework of a theory, we need to form a model of that phenomenon which redescribes it in terms which are amenable to mathematical, theoretical treatment' (p. 200). To summarize, statistical or mathematical research on complex phenomena, whether natural sciences or other sciences, contains numerous assumptions that may not match with the phenomena or their explanations. This is not exclusively a social-science research issue.

Objective observations and truth

Outside observers and involved researchers. Orlikowski and Baroudi (1991) associated positivist[5] natural science research with the view that the researcher 'does not intervene in the phenomenon of interest' (p. 9). Walsham (1995a) distinguished two roles in interpretive research, that of 'outside observer and that of involved researcher' (p. 77). The latter researchers 'are in some sense conducting action research by influencing what is happening in the domain of action' (Walsham, 1995a: 77). Similar roles can be found in the natural sciences. A biologist may only observe animals with as little intervention as possible. However, examples of intervention can be found, such as when the function of a specific gene in animal models is studied using genetic engineering to remove that gene from a living mouse and observe whether normal development changes. This method has been widely used in biology research, as in the case of using the p53-deficient mouse (Donehower, 1996). To summarize, IS readers learn that natural science–oriented researchers '[do] not intervene in the phenomenon of interest' (Orlikowski and Baroudi, 1991: 9). Natural science research can, however, intervene 'in the phenomenon of interest'.

Objective basis for observation versus interpretation. Some IS literature has suggested that natural sciences are objective, requiring no interpretation or judgement, while interpretive research requires judgement, with knowledge being socially constructed. To begin with, McBride (2018a) suggested that scientific philosophy 'excludes interpretation and judgement as an element of research' (p. 165). This implies that the 'real' sciences do not contain elements of interpretation or judgement. Others have reported how positivist (natural science) research, which is 'dominant in information systems research' (Orlikowski and Baroudi, 1991: 8), assumes 'that as impartial observers, researchers can objectively evaluate or predict' (Orlikowski and Baroudi, 1991). In turn, the 'interpretive method of research', which is opposite to the 'positivist' natural science approach, assumes that 'our knowledge of reality is a social construction by human actors' (Walsham, 1995b: 376) and that 'value-free data cannot be obtained, since the inquirer uses his or her preconceptions to guide the inquiry in order to guide the process of enquiry' (Walsham, 1995b: 376). Similarly, Walsham (1995a) noted that interpretive researchers should not 'be viewed as that of an objective reporter, since the collection and analysis of data involves the researcher's own subjectivity' (p. 77). In turn, the positivist (natural science) scholars assume objective data (Walsham, 1995b: 376).

These aforementioned claims about the interpretive versus 'positivistic' natural sciences are questionable. For example, a recent article published in the journal *Philosophy of Science* claimed that 'the theory-laden, man-made nature of data makes it difficult to conceptualize them as providing objective evidence for theories' (Leonelli, 2015: 812). Moreover, 'data [in natural sciences] reflect scientists' interests, background knowledge, location, instruments, and research strategies' (Leonelli, 2015: 812).

To explain 'theory-laden', the following example can be considered.[6] If natural scientists look at a planet through a telescope, or look at a chemical or biochemical substance through a microscope, this research requires interpretation whereby the 'inquirer uses his or her preconceptions to guide the inquiry'. A concrete example is primary brain lymphoma (a type of cancer) in cancer biology. Under a microscope, the growth pattern (angiotropism) of primary brain lymphoma resembles sarcoma (a different type of cancer), and primary brain lymphoma was long confused with sarcoma before more specific ways of recognizing it through a microscope were identified (Bhagavathi and Wilson, 2008). Even a trained cancer biologist, who may have 'preconceptions' of sarcoma but may lack the same preconceptions of how primary brain lymphoma looks under a microscope may confuse these lymphomas. In such a situation, how can information not be socially constructed? When the researcher's assumptions, educational background, or preconceptions change, then the interpretation of observations may also change.

To summarize, the idea that (generally) natural science observations are objective and value-free and do not require any interpretation is simply not supported by the current understanding of the philosophy of natural sciences (see Leonelli, 2015).

Natural sciences as hermeneutics. Klein and Myers (1999) implied that the 'natural science model of social science' (p. 67) is unsuitable for 'interpretive studies'.[7] As a result, they proposed principles for interpretive research that 'appl[y] mostly to the conduct and evaluation of interpretive research of a hermeneutic nature' (p. 68). Following Heelan (1983, 1997, 1998), we wish to introduce the possibility that natural science research is also hermeneutical in some respects. Before making the argument, it is helpful to briefly introduce hermeneutics. While Klein and Myers (1999: 70) highlighted Gadamer and Ricoeur as the 'most well-known exponents' of hermeneutics, hermeneutics was originally a method for explaining and interpreting the Bible (exegetics). In the 17th century, Dannhauer separated three areas of use for hermeneutics: Holy Scripture, the literature of classical antiquity, and legal texts (Mautner, 1996: 188). Later, the theologist Friedrich Schleiermacher developed a general theory of interpretation that extended the application of hermeneutics beyond Holy Scripture to the interpretation of any text. Dilthey and others later dubbed the humanities (*Geisteswissenschaften*) as hermeneutical (Mautner, 1996: 188). In the philosophy of science, Heelan (1983) in particular argued that any perception, 'including observation in natural science, is hermeneutical' (p. 181). This means that 'the perceiver (or observer) learns to "read" instrumental or other perceptual stimuli as one learns to read a text' (Heelan, 1983: 181).

Although discussion of how specific hermeneutical concepts fit natural science does not fall within the scope of this article (see instead Heelan, 1983, 1997, 1998), a simple example can be provided. Sociology has a well-known tradition of separating the natural and social sciences. For example, Mannheim (1936) suggested that natural science subject matter is 'static and timeless' (note that this statement is questionable, see section 'Laws'). Now consider Heelan's (1983) more hermeneutical characterization of understanding: 'Search for the holistic understanding of a particular text is always situated at a definite time and place in history: the text is not assumed to have one timeless meaning' (p. 183). If the word 'text' is replaced with 'observation' or 'instrument reading', to what extent can this characterization also be applied to the natural sciences? If the natural sciences were 'static and timeless' (Mannheim, 1936), then even this simplistic hermeneutical characterization fails.

However, numerous examples can be found in the natural sciences in which the researcher's observations do not have 'one timeless meaning'. Contagious cancer theory in cancer biology is a case in point. Two scholars proposed separately and independently (in 1649 and 1652) that cancer might be contagious after observing breast cancers within the same household. One could make the same assumption today based on similar observations. However, the meaning of this observation would be totally different now, as it is currently believed that a hereditary component may be involved in such cases. In addition, the practical (oncological) implication of the same observation is different today.[8] Numerous similar examples could be given in which the meaning of the same observation has radically shifted, showing that the meaning of one type of observation has not been timeless. Heelan (1983) notes that 'what counts as a satisfactory answer [to scientific problems] depends on the time and place, and the cultural interest of the scientific community' (p. 201). Similar ideas have also been reported by Laudan, (1978, 1984) Recently, Leonelli (2015) argued that, in (natural) sciences, 'the question "What is data?" can only be answered with reference to concrete research situations, in which investigators make specific decisions about what can be used as evidence for which claims' (Leonelli, 2015: 818).

A natural science model is distinguished from interpretive research (Klein and Myers, 1999: 67), and a natural science model of social science must consider that natural science research is often based on some data. The data in natural science should not be believed to have one static and timeless meaning. Rather often, if not always, data (when used by scientists) require interpretation that may contain hermeneutical aspects. Regarding natural sciences as hermeneutical does not mean that are no differences in the use of hermeneutics between the natural sciences and IS. But the original conception of hermeneutics (i.e. designed to interpret text that is, for example, 2000 years old) may entail different challenges than those in typical interpretive IS research, in which research subjects can be interviewed.

As noted, natural science knowledge is theory-laden, the meaning of data is often tied with the research purposes, and the meaning of the same observation may shift. For example, natural science

> researchers often produce data without knowing exactly which phenomenon they may document. Data production, particularly for high-throughput biological data, can and does happen simply because scientists have access to a given instrument and/or because they hope that consulting those data may yield new questions or insights on as-yet-unknown phenomena. (Leonelli, 2015: 818)

However, other questions still remained unanswered. Some social scientists (according to the reviewers) may assume multiple socially constructed truths at the same time. Does a model in natural science research represent the truth or assume one truth or multiple truths?

Distorting the assumed 'truth' and natural sciences. In IS, the view that 'truth exists and somehow that truth can be extracted, explicated, and codified' is related to views from natural science (Hevner et al., 2004: 98). In addition, truth as the goal is associated with natural sciences. Consider, for example, that '[i]nquiry in the natural sciences pursues the goal of truth.' (Lee, 1989: 29) or that '[t]he goal of behavioural-science research [that has roots in natural sciences][9] is truth' (Hevner et al., 2004: 80). These views are problematic as general claims on natural sciences. Philosophers such as Leonelli (2015) claim that scientific 'data do not have truth-value in and of themselves, nor can they be seen as straightforward representations of given phenomena'. (p. 811). But the issue is not only data. If the many products resulting from natural science inquiry are examined, they hardly meet the truth requirement assigned by IS natural science views (Hevner et al., 2004; Lee, 1989). For example, the fundamental laws of physics are not, strictly speaking, true: 'Fundamental laws [of physics] are not true, nor nearly true, nor true for the most part' (Cartwright, 1989:

175). In fact, 'if we require truth we have very few or no known laws' (Teller, 2004: 731). Similarly, it has become common in modern philosophy of science to note that major natural science accounts purposefully distort the truth by containing what philosophers call 'deliberate misrepresentations' (Love and Nathan, 2015: 761), 'strategic falsehoods', or 'ideal concepts' (Nagel, 1961). For example, '[t]he gas laws . . . describe the behaviour of ideal gases, *not real gases*' (Suppe, 1972: 12). In turn, 'in molecular biology, the causal relations . . . are deliberately misrepresented on a regular basis' (Love and Nathan, 2015: 764). Laws on ideal gas or models on molecular biology containing deliberate misrepresentations can hardly be said to represent the truth, yet modern philosophy of science often regards such falsehoods or misrepresentations as both *standard* and *necessary* practice in molecular biology or physics (e.g. Love and Nathan, 2015; Wayne, 2011). Not understanding these deliberate misrepresentations or falsehoods may cause major misunderstandings.

Furthermore, according to IS sources, theories (in the natural science view of behavioural-science research) 'are evaluated against the norms of truth or explanatory power and are valued only as the claims they make are borne out in reality' (Hevner et al., 2004: 80). Taking this criterion literally could render the fundamental laws of physics as not valued. Theories with 'ideal concepts' (e.g. laws on ideal gas), or those in which causal connections are deliberately misrepresented, are not accepted because they 'are evaluated against the norms of truth' (Hevner et al., 2004: 80). Numerous natural science accounts have been accepted even though they contain concepts that are known to be purposefully false (Cartwright, 1983; Nowak, 1980). Hevner et al. (2004) also used the term 'approximations' but maintained that such approximations 'are evaluated against the norms of truth' (p. 80). However, how this can be the case and why IS behavioural studies are 'approximately true' is unclear.[10] A study does not turn into an approximately true one by saying so or by believing such is the case.

To summarize, natural science theorizing commonly involves crafting various different idealized models for various purposes, which often contain deliberate falsehoods or misrepresentations (Love and Nathan, 2015; Wayne, 2011). In such cases, the model should not be assumed to represent the truth. Natural scientists seem to sacrifice the assumed truth for achieving some other (higher) purpose (Love and Nathan, 2015; Teller, 2001). IS models most likely do so as well, even though current IS philosophy may not understand this.

General laws, deterministic philosophy, and transferability of laboratory findings

This section discusses IS natural science beliefs that assume laws or determinism and also considers the applicability of laboratory studies to real settings.

Laws. From the 1940s to 1960s, many philosophers believed that science explained and predicted with laws (Beatty, 1980). The major account of how laws factored in explanation and prediction was the deductive-nomological method of explanation.[11] The influence of law-based philosophy from these decades is visible in IS. Evaristo and Karahanna (1997) reported that a considerable portion of IS research is based on 'the deductive-nomological method of explanation' (p. 32), which require one or more laws. Moreover, '[t]he behavioural-science paradigm has its roots in natural science research methods', and this paradigm 'seeks to develop and justify theories (i.e. principles and laws)' (Hevner et al., 2004: 76). Furthermore, 'positivistic' natural science researchers have been reported as using surveys and experiments with inferential statistics to 'discover causal laws' (Orlikowski and Baroudi, 1991: 10) or 'universal laws' (Orlikowski and Baroudi, 1991: 12). McBride's (2018a) view of science also included laws. In addition, seminal design-science articles have referred to laws or natural laws (Gregor and Hevner, 2013; Hevner et al., 2004). For instance, the most frequently cited design-science article stated that 'laws are crucial components of design-science research' (Hevner et al., 2004: 88).

Given the stated importance of laws, the definition of a law must be determined. Orlikowski and Baroudi (1991) discussed causal, or universal, laws. Indeed, the standard conception of a law is universal: 'Traditionally, the word "laws" has been reserved for universally applicable, exceptionless generalizations' (Teller, 2004: 731). Also the deductive-nomological model assumed exceptionless laws.[12] With the standard definition of law concept, if the law is not completely true, without exceptions, then the law does not enjoy the status of scientific law.

The last 30 to 40 years in the philosophy of science have radically challenged the traditional definition of laws. True universal laws have been difficult to find, even in physics: '[W]hat happens on most occasions is dictated by no law at all' (Cartwright, 1980: 161). Giere (2005) was even more sceptical: '[W]e must reject the idea that the content of science is encapsulated in universal laws' (p. 287). Outside of physics, philosophers have argued that molecular biology and psychology are mainly explained not by laws, but by mechanisms (Darden, 2008).[13]

To summarize, deeming IS statistical or probabilistic research as discovering or testing laws, let alone universal laws, is questionable and misleading. The standard meaning of law assumes universal (i.e. exceptionless) generalizations (e.g. all men are mortal). However, statistical studies showing, for example, that ease of use explains information technology (IT) use, do not produce a universal (exceptionless) generalization (like 'all men are mortal'). The generalization (e.g. ease of use explains IT use) is expected to have exceptions. Moreover, expecting laws in IS is questionable given that philosophers have noted the difficulty of finding genuine laws even in physics (Teller, 2004) or biology (Beatty, 1980).

Determinism. If true universal laws are difficult to find even in physics, where they are expected most (Cartwright, 1983; Giere, 2005), what can be said about determinism? Orlikowski and Baroudi (1991) held that natural science–oriented ('positivistic') research 'techniques encourage deterministic explanations of phenomena' (p. 12). In turn, interpretive research (opposite to the positivistic natural science view) has a 'nondeterministic perspective' (Orlikowski and Baroudi, 1991: 5; Walsham, 1995b: 384). Furthermore, McBride (2018a) not only regarded quantum physics as deterministic, but he also deemed 'deterministic philosophy' (p. 165) to be a characteristic of science. Readers therefore can arrive at the conclusion that, if a field of science is not deterministic, then it is not 'scientific'. According to McBride (2018a), 'deterministic philosophy . . . take[s] . . . cause and effect linkages as objective, fixed.' and 'expects reproducible cause and effect' (p. 165), while IS concepts are variable.

The problem of these claims is that countless phenomena, or accepted theories or models thereof, in natural sciences have turned out to be indeterministic – at least currently. For example, quantum physics is reported to be indeterministic (Mautner, 1996). A discussion of determinism runs the risk of being pointless, unless we state what is determinism and what is indeterminism. A textbook characterization of determinism links it to universal natural laws: 'The natural laws and the way things are at times determine the way things will be at all times' (Loewer, 2006: 327). In other words, a universal (exceptionless) law can be said to be deterministic (Cartwright, 1979). If a knowledge claim (or the 'law') is not exceptionless, then it is indeterministic (Cartwright, 1979). For instance, probabilistic claims are not deterministic; they are indeterministic (Cartwright, 1979).

Let us consider a simple example from carcinogenesis in (cancer) biology. The claim '[s]moking causes lung cancer' (Cartwright, 1979: 419) would be a true deterministic, causal claim (a deterministic law) if all smokers always got lung cancer. However, some smoke for 30 years and do not develop lung cancer, while others develop lung cancer without ever smoking (including passive smoking). Thus, 'smoking causes lung cancer' cannot be correctly conceived as a deterministic claim (deterministic and causal law).[14] For example, some scientists regard carcinogenesis (cancer formation or causation) as a matter of 'bad luck' (Tomasetti and Vogelstein, 2015: 78). Anyway, who will get certain types of cancer and who will not get them cannot be known with certainty.[15] In such cases, the causality is not deterministic or probabilistic, but it can be somewhat random at the individual level.[16]

Morever, McBride (2018b) stated that science 'focuses on achieving the same result every time' (p. 220). Here, it is worth emphasizing that, quite frequently, even the best laws hardly give 'the same result every time' in real settings and in different individual cases. Chalmers (1993), for instance, notes that 'there is not a good fit between the claims made by the laws of science and happenings in the world'. For example, 'Falling objects, such as Autumn leaves, rarely descend to the ground in a way that conforms to Galileo's law of fall' (Chalmers, 1993: 196).

To summarize, the natural sciences should not be assumed as, by definition, deterministic. Critics might reply that biology and biochemistry can be governed by deterministic laws; they just have not found them yet. However, before that happens (if it ever happens), many modern natural sciences can be assumed to be nondeterministic in actual settings (e.g. outside of laboratory settings). Generally, requiring determinism or 'the same result every time' (McBride, 2018b: 220) in real settings is simply asking too much (at least currently) from scientific research.

Isolation in the laboratory rarely transfers to real settings. McBride (2018a) suggested that molecular biology can control and isolate a phenomenon in the laboratory to make predictions, while 'social science experiments' rarely 'present anything of value in the real social situation' (p. 168). Readers may interpret this as meaning that natural science laboratory experiments transfer easily to real situations (and perhaps vice versa) and that the natural sciences can therefore isolate. However, this is not generally the case.

One important reason for using both laboratories and the method of isolation (Mäki, 1992, 2004) is that the actual phenomenon is too complex to handle without isolation. Isolation is, therefore, primarily a method for coping with complexity, often with the costs of decreasing realism and misrepresenting the actual phenomenon.[17] In isolation, a scholar focuses on examining one set of entities and omits the rest (Mäki, 1992, 2004). For example, biochemical pathways may contain hundreds of activities and components that have complex reticulated connections. One study may examine just one aspect of one component, ignoring all the complex reticulated connections found in real settings (i.e. without the use of isolation). Such isolation often sacrifices the assumed 'truth', as it leads to deliberate misrepresentation of the phenomenon (see section 'Distorting the assumed "truth" and natural sciences').

Many drugs show efficacy in natural science laboratories and may even have a molecular basis (theoretical explanation using IS jargon) for their potential efficacy, but they fail in further studies in living organisms. Vascular endothelial growth factor inhibitors are one example (Chau and Figg, 2012). Blood vessel formation (angiogenesis) is important in cancer progression, and blocking this event was thought to be effective; it was thought that tumour cells would lose their nutrient supply and die. However, real-life data from cancer patients indicated that this was not the case (Chau and Figg, 2012). One reason is that the cancer of each patient was dynamic and could develop in a unique manner. Therefore, if one step of a complex mechanism is understood, and this step is manipulated in a laboratory setting, the result in a living organism ('real settings') is often not as expected.

To summarize, it is problematic to claim that IS experiments have no value in real settings, while natural science laboratory experiments have value. The reasons for using laboratories or other counterfactual settings (e.g. mathematical models) is not necessarily the direct transferability of the results to real settings, but rather something else (see next section).

Discussion

A possible explanation of natural science views in IS

The philosophy of science, especially from the 1930s to 1960s, focused on reconstructing generic accounts of science, often inspired by philosophers' interpretations of physics (Giere, 1996). Today, such views are widely rejected in their original forms, even in the philosophy of physics. For example, a philosopher of physics has deemed such views as 'the misdescription of physics by the philosophy of science' (Teller, 2001: 395). In addition to misdescribing physics (Teller, 2001), these old philosophical accounts also typically ignored the differences between various natural sciences (Diesing, 1991). For example, physics often explains using idealized laws (Teller, 2001), while life sciences, such as molecular biology, often explains using mechanisms (Darden, 2008). However, IS natural science articles do not note even such basic difference.

Mistaking 'the misdescription of physics by the philosophy of science' from the 1930s to 1960s (Teller, 2001: 395) for 'real' natural sciences may explain some basic confusions in IS, social sciences, and business schools on natural sciences. Furthermore, many IS beliefs about natural science could hinder progress in the natural sciences if such beliefs were to be imposed there. Even more important is understanding that confusions on natural sciences may be deleterious (and might have already done some damage) to IS research, doctoral training, and publication expectations for top IS journals.

Implications for IS research

Methodological issues. Depicting natural science research as statistical and quantitative, as opposed to qualitative, ignores the (1) complexity and variety of methods and instruments used, and (2) the importance of qualitative observations in many natural sciences. For example, numerous scientific breakthroughs in natural science have stemmed from qualitative observations. Arguably, qualitative observations could be important sources for IS scholars as well. IS departments should not educate their students to use quantitative methods and overlook qualitative methods on the basis that the former are deemed as 'the only legitimate methods for use in social science' (Evaristo and Karahanna, 1997: 39) while the latter are not.

Furthermore, in IS, the use of statistical or mathematical models may lead to simplification or misrepresentations if the assumptions underlying the statistical or mathematical methods are different from what is assumed for the phenomenon or its explanation. IS methodologists should move from merely marketing methods as accepted to describing the underlying assumptions of the methods (see more below on truth).

Objective observations and value-free data. Generally, data in natural science or IS are not objective or value-free, and data require interpretation. For example, survey instruments are ultimately socially constructed. Statistical techniques are also man-made and, in a way, socially constructed. In addition, in IS, the results are often interpreted in the light of some theory. Moreover, the survey instruments or experiments are also often designed to test some theory. Alluding to value-freeness, 'impartial observers', or scholars who 'can objectively evaluate or predict' (Orlikowski and Baroudi, 1991: 8) in such cases is misleading because the observations are not theory-free (or free from background assumptions). Rather, it is quite the opposite; they are guided by a number of theoretical (and other background) assumptions. IS scholars should not believe that simply because they use numerical data, the data are objective and value-free and do not include social constructions, thus being free from any interpretation. Instead, future IS philosophy should be tasked with analysing and illustrating how various well-known philosophical theses, such as under determination, the theory-ladenness of the observation, or related theses by Kuhn (1970) and Feyerabend (1975), typically play a role in different IS research strategies.

The norm of truth. Requiring truth can be harmful in IS because it can imply a utopic illusion that a phenomenon is so simple that one model can capture the truth. Virtually all phenomena, even in physics, are so complex that any model or study must, by nature, purposefully simplify the phenomena. Such moves (e.g. simplifications) often (some philosophers believe always) result in the phenomenon, or its explanation, being purposefully misrepresented. Thus, even the fundamental laws of physics are not, strictly speaking, true, and they tend to provide false predictions in real settings (Cartwright, 1983, 1989).[18] If physicists cannot present any fundamental law without misrepresentations (Cartwright, 1983) because the phenomenon (or what explains it) is too complex, then why should IS phenomena (or what explains them) be considered less complex? Assuming that IS phenomena are not simpler and more lawlike than those captured by the fundamental laws of physics, then an important task for future IS philosophers is to reveal how the complexity in natural sciences is managed using various isolation and idealizations tactics and how such activities are also necessary in IS.

Furthermore, many natural science phenomena are only accessible through some research instruments, which often (if not always) distort the assumed truth. Similar examples in IS should be found concerning how scientific studies can capture truth when scientists use statistical models containing false assumptions with respect to the phenomenon (or its explanation). For example, if statistical methods assume linearity, while the phenomenon is assumed to be non-linear (see also Treiblmaier, 2019), then how the study can use such a method to capture the truth must be questioned. A task for future IS philosophy is to unveil the underlying methodological assumptions and what implications these have for IS studies, so that IS scholars can decide which method to use.

Universal and deterministic (true) laws. Since the 1960s, it has been discovered that the fundamental laws of physics are not true (general) laws (Teller, 2004). Therefore, characterizing IS behaviour research as discovering universal or deterministic laws or suggesting that laws are important in design-science research is problematic and misleading. For example, requiring true universal/deterministic laws would have seriously hindered current understanding of physics or biology. True laws cannot really be expected in IS research, when such laws are difficult to find in physics (Teller, 2004) and biology (Beatty, 1980).

If true laws (that explain or predict) do not exist in IS, and most IS models do not really contain true laws, then the question arises concerning what does the explanatory work in IS in qualitative, quantitative, or design research. For example, is IS quantitative research providing statistical explanations or statistical predictions? Answering this question requires outlining a philosophical account of what counts as statistical explanations or statistical predictions. Or, are IS studies offering mechanism-based explanations, and why? These questions must be answered by future research because the generalizability issues of knowledge claims are expected to vary between laws, statistical claims, and mechanisms. Without these considerations, a risk exists that law-based beliefs provide a false benchmark on the generalizability of the IS research, as indicated by editorial statements, ‘affirming that gravity works in my kitchen’ is not publishable (Rai, 2017 p. vi). The application or generalizability of universal laws is straightforward: they apply generally as such, so no case-by-case applications are needed. However, if candidates for ‘best laws’ in IS turn out be rough statistical generalizations, then the application of statistical generalizations to individual cases is not straightforward. Rather, it is complex, and the results are expected to vary at the individual level.

Furthermore, the commonality of one-time studies in IS may hail from the belief that the world is governed by laws. If there is a true universal law, then there would be little need to examine its change. It cannot change; otherwise, it is not a true law. However, if a phenomenon does not accord with true laws (e.g. if users’ reasons for IT use are not invariant but subject to change), then the phenomenon is beyond the resources of one-time studies to examine it adequately. If this is the case, then replications should not be undervalued (cf., Rai, 2017). If there are no true, general laws in IS, then the results should be expected to vary in different settings, which studies in different contexts will reveal. Provided that there are no true general laws in IS, editors should welcome studies that examine models in different settings by trying to find situations that the explanatory factors fail to explain.

The transferability of the laboratory findings to real settings. Generally, in natural science, isolated laboratory studies do not apply to different real situations as such without any modifications. However, laboratory studies can be highly useful as a starting point in natural science or IS. IS research could also be seen as a long-term research programme in which the research starts first with a laboratory setting or some ‘ideal conditions’ and later moves to test the method in different ‘real’ settings. Moreover, countless IS research questions are lacking (good) possibilities to test them in real settings (see section ‘Differences between natural science methods and statistical or mathematical methods’). Laboratory settings, mathematical models, and thought experiments may allow for testing some questions that are difficult to test in real settings, and such studies should be valued in IS. Laboratory studies in IS decrease realism, but this is also the case with laboratory studies in natural sciences. Often, if not always, laboratory studies (whether in natural science or IS) trade realism for gaining something else, such as potentially useful information. The complex dynamic of research from life sciences to practical applications is something that IS research could learn (with some modifications). For instance, one set of scholars could specialize in laboratory studies, while another could specialize in more applied research. A third set of scholars could specialize transferring the results to practice, and a fourth set of scholars could observe the practice, providing feedback to the laboratory researchers.

Conclusion

A look at modern (philosophy of) natural sciences challenges many IS natural science beliefs, including the beliefs that all natural sciences (1) use quantitative (and not qualitative) methods, are (2) objective and (3) deterministic, and commonly capture the truth in real settings. By scrutinizing the natural sciences, a totally different view is gained from that which is presented in many seminal IS articles. For example, understanding how the assumed ‘truth’ is often misrepresented in natural sciences to make complex and indeterministic phenomena manageable can radically change the view that the best IS models and theories give true predictions and are accurately generalizable to real settings.

As another example, natural scientists should understand that their methods may not be objective but rather contain assumptions that often misrepresent a phenomenon (e.g. they might assume linearity even though the phenomenon is not linear). A similar realization among IS scholars may make it more acceptable to discuss false assumptions underlying IS research methods. This discussion is important for the practical applicability of IS results and continuing research programmes. If IS research methods contain assumptions that are false in real settings (e.g. linearity), then this research must be followed up with other methods and further studies if practical applicability is to be achieved. Many differences exist between IS and the natural sciences, and thus IS should not blindly follow the natural sciences. However, there is much that IS research could learn and adopt from natural science research.

Finally, our examples from natural science do not form a 'natural science model'. The substance and methods of the different natural sciences are too broad to be covered by a single model. For instance, the fundamental laws of physics (Cartwright, 1983) are, in numerous ways, totally different from the mechanisms in biology or biochemical signalling pathways (Thagard, 2003).

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Notes

1. Much of IS research has been influenced by 'a research tradition that has its roots in the natural sciences' (Orlikowski and Baroudi, 1991: 7).
2. We do not agree that 'quantitative methods were originally developed in natural sciences' (Myers, 2013: 7) because many methods developed in natural science may not fit well with the qualitative/quantitative dichotomy (see section 'Objective observations and truth'). Moreover, mathematical and statistical methods are often developed by mathematicians and statisticians, not by natural scientists.
3. Mingers (2003) criticized this dichotomy; albeit, the critique was not related to natural sciences.
4. For example, cell size control and cell division, both important in embryogenesis, normal tissue regeneration, and cancer, have been studied extensively for decades using observations under a microscope (Conlon and Raff, 2003; Lord and Wheals, 1981).
5. Some writers on interpretivism (e.g. Walsham, 1995a, 1995b) do not view it as opposed to natural science but rather as opposed to 'positivism'. However, when they make such a dichotomy, they cite studies (e.g. Orlikowski and Baroudi, 1991) that describe 'positivism' as 'a research tradition that has its roots in the natural sciences' (p. 7). Numerous other IS articles (e.g. Evaristo and Karahanna, 1997; Iivari, 2008; Mingers, 2003; Ngwenyama and Lee, 1997) associate positivism with the philosophy of the natural sciences. For example, Lee and Hubona (2009) noted that 'positivism refers to a genre of social science research that, among other things, regards the natural sciences as the model for the social sciences to live up to' (p. 238). Hevner et al. (2004) noted that

   > [p]hilosophical debates on how to conduct IS research (e.g., positivism vs. interpretivism) have been the focus of much recent attention . . . The major emphasis of such debates lies in the epistemologies of research, the underlying assumption being that of the natural sciences. (p. 98)

   The point of this article is not to examine 'positivism' or whether IS beliefs are correct in the light of the philosophy of positivism. The first author's view of IS beliefs on logical positivism is published by Siponen and Tsohou (2018).
6. This idea was originally presented by Hanson (1958). He claimed that different observers with different underlying beliefs 'experience' or 'see' different things (theory-ladenness). These differing perspectives exist even before any interpretation begins.
7. 'While the conventions for evaluating information systems case studies conducted according to the natural science model of social science are now widely accepted, this is not the case for interpretive field studies' (Klein and Myers, 1999: 67).
8. In the 17th century, contagious cancer theory suggested that patients should be isolated outside cities and towns to avoid the spread of cancer. Today, the oncological implication of this observation suggests genetic testing for healthy female offspring to estimate their risk of developing breast cancer. If a hereditary component is found in, for example, a certain gene mutation, a close follow-up for healthy family members is conducted to detect possible breast cancer at early stages, and sometimes prophylactic mastectomy (removal of breast tissue by surgery) is performed before cancer develops.
9. 'The behavioural-science paradigm has its roots in natural science research' (Hevner et al., 2004: 76).
10. For example, 'approximate truth is not a kind of truth. Indeed, it is a kind of falsehood! Approximately true implies "not exactly true", which means false' (Giere, 1988: 106).
11. Hempel and Oppenheim (1948) outlined the logic of scientific explanation. Later, Hempel (1965) referred to this specific model by Hempel and Oppenheim (1948) as 'the deductive-nomological model' (p. 380). The deductive-nomological method of explanation has some similarities with Popper's (1935) view of causal explanation. Therefore,

the deductive-nomological method of explanation is sometimes referred to as the ‘Popper-Hempel theory of explanation’ (Von Wright, 1971: 175). Hempel used another model, the inductive-statistical model, which covers statistical explanations. This model is not the same as the deductive-nomological method of explanation.

12. ‘What are the characteristics of lawlike sentences? First of all, lawlike sentences are statements of universal form, such as . . . “All metals are conductors of electricity.”’ (Hempel and Oppenheim, 1948: 153).
13. According to Machamer et al. (2000), ‘The traditional notion of a universal law of nature has few, if any, applications in neurobiology or molecular biology’ (p. 7). According to Darden (2008), ‘Biologists rarely appeal to laws in giving explanations’ (p. 959).
14. It is more correct to say that smoking raises the probability of developing lung cancer (under certain conditions).
15. For example, random gene mutations are important in carcinogenesis (Tomasetti and Vogelstein, 2015).
16. ‘Causal capacities may usefully be divided into three kinds: deterministic, random, and probabilistic. A deterministic capacity is one which, under specifiable circumstances, always produces its effect. A random capacity sometimes produces its effect and sometimes does not, but nature does not determine how often or how regularly it does so. A probabilistic capacity also operates only sometimes, but the strength of the tendency to produce the effect is nomologically fixed . . . if there are genuinely random capacities, it is obvious that there are capacities that cannot be reduced to quantitative probabilities’ (Dupre and Cartwright, 1988: 522).
17. ‘The cell and its myriad constituents compose an extremely sophisticated apparatus; a realistic representation of this plethora of entities and interactions—assuming that such a “complete” depiction is even feasible—would make the description impractical and the explanation unilluminating’ (Love and Nathan, 2015: 764).
18. ‘[F]undamental laws are not true, nor nearly true, nor true for the most part’ (Cartwright, 1989: 175). Moreover, ‘if the fundamental laws [of physics] are true, they should give a correct account of what happens when they are applied in specific circumstances. But they do not. If we follow out their consequences, we generally find that the fundamental laws go wrong’. (Cartwright, 1983: 13)

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