

## Chapter 2

# Information Systems Research as a Science

### 2.1 Principles of Scientific Inquiry

At one time, a friend of mine gave me a book to inform me as to the nature of science.<sup>1</sup> My immediate response was that I did not need such a book; at that stage I was already tenured, promoted to Associate Professor with a good track record in publishing, and the promise of many publications to come. Clearly, I thought, I know what science is about.

I couldn't have been more wrong. This is not to say that all my prior efforts were fallible, misguided, and successful only by chance; rather that learning about the basic principles of science opened my eyes to some fundamental elements that govern much scholarly work.

I argued above that scholarly research worthy of a doctoral degree could be described as “scientific research” that conforms to a “scientific method”.

Science is the attempt to derive knowledge from facts through certain methods in a systematic and organised way. It is important to note that derivation is meant here in a logical rather than temporal way. It does not necessarily mean the facts come first. Historically, two categories of science have evolved:

The **Natural sciences** concern the study of naturally occurring phenomena and include such fields of inquiry such as chemical sciences, physical sciences, life sciences, and the biological sciences. The phenomena under scrutiny are real and tangible such as bodies, plants, or matters – although some objects in some fields like subatomic particles, chemical elements, or microscopic organisms are admittedly more difficult to observe.

By contrast, the **social sciences** concern the study of people or collections of people. These sciences are composed of psychology (studying individual behaviours), sociology (studying behaviours of groups of individuals), organisational

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<sup>1</sup> The book, by the way, is Alan Chalmer's brilliant essay “What is this thing called science?” (3rd edition, University of Queensland Press, 1999).

science (studying the behaviours of corporate organisms), and economics (studying firms, markets and economies). I often make the general observation that all studies involving humans are part of the social sciences.

The distinction between natural and social is very important to understand because the inquiries or research processes for the two are very different. The natural sciences are referred to as the “exact sciences”<sup>2</sup>; these inquiries rely on precise and accurate measurements of phenomena or their properties. Examples of such work are readily found in any high school chemistry or physics department. In the natural science of physics, for example, properties such as the speed of light or gravity have been calculated and will remain invariant. This serves as an illustration but in the natural sciences, definitions and measurements are by no means always exact and precise. Heisenberg’s uncertainty principles state a fundamental limit on the accuracy with which certain pairs of physical properties of a particle, such as position and momentum, can be simultaneously known. Still, for the purpose of our argument here, let us presume that natural sciences are exact.

The social sciences are even further away from precision. In the social sciences, phenomena as well as measurements are often vague, imprecise, non-deterministic, and ambiguous. Think about a study that examines whether happy people sleep more or less than unhappy people. Problems abound when we try to understand let alone precisely measure what happiness means, or when we try to isolate the true cause of variation in sleep length. We all know that for any two given days people will not likely sleep for the same amount of time, and there are plenty of reasons for this variation: there could be noise in the bedroom, light shining through the window, more or less wind breezing through the room, the person could have eaten differently in turn affecting their sleep patterns, the person could have had a good dream or a nightmare, and so forth. Many reasons may contribute to different durations of sleep – and but one of them may be related to some form or other of happiness!

One of the many manifestations of this issue is the challenge of *measurement error*. Measurement error is invariably present in the social sciences. This issue recognises that because of the complexity, vagueness, and ambiguity of many of the phenomena under study, many of which we cannot faithfully define or isolate precisely, there will always be imprecision in the way we study our phenomena of interest, and the findings we in turn obtain.

We will return to this issue later in this book. The point I am making here is that students need to be cognisant of the fact that, as an information systems scholar – a discipline that concerns information technology in use by [individuals/organisations/economies/other groups of people], by definition, is a part of the social sciences. As soon as our investigation concerns a human element, imprecision, vagueness and ambiguity creeps into our research.

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<sup>2</sup>I should point out here that this is an overly simplistic account of the relationship between the truly exact sciences (mathematics) and their applications in natural sciences such as physics. But I did promise not to delve into tangential discourses.

The view that I am subscribing to is that the goal of scientific inquiry is to discover laws and propose theories that can explain [natural or social, tangential or latent] phenomena in the worlds that concern us. This is what we call scientific knowledge produced as an outcome of scientific inquiry. Of course, this is but one view on the topic but a rather generally accepted view. Still, keep in mind that others (perhaps even yourself) may choose to phrase the goal of science in different terms.

The challenge as alluded to above is that often this knowledge remains imperfect, vague, and sometimes even incorrect. This is especially so in the social sciences because of the measurement error that creeps into scientific studies.

The key point to remember is that all scientific knowledge, by definition, is merely a set of *suggested explanations* of a particular phenomenon. I often illustrate this with the very basic example of stating that several hundred years ago we *knew* that the earth was flat. Our theories which were mostly inspired through western religion as well as the limited measurements of the time (look at the horizon and see how the ocean “ends” at a certain line), suggested this knowledge to be appropriate. Now we *know* that this theory of the earth wasn’t actually correct. For one thing, you can sail around the earth. Since, we have also ventured into space and seen from that distance that the earth has a spherical shape.

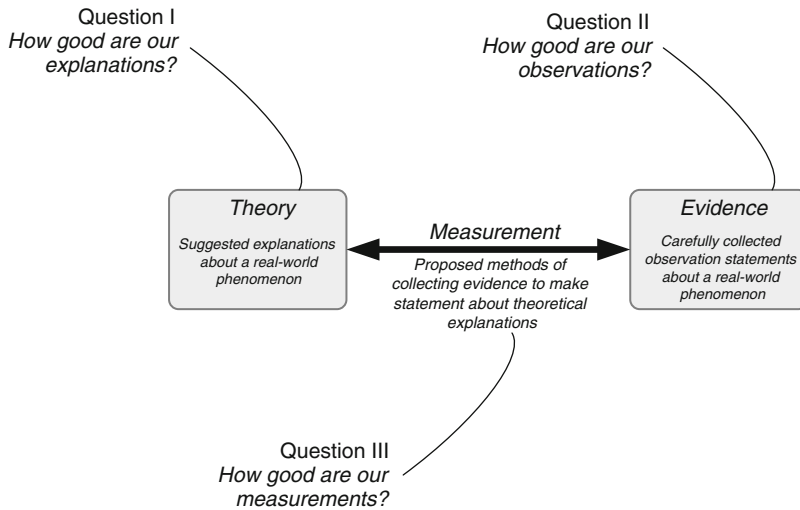
Again, what is the point? The point here is that the body of scientific knowledge, the outcome of all research to date, is the *current accumulation* of theories, evidence, and measurement methods in a certain domain (for example, medicine, management, education, information systems and so forth).

As you can see, this definition makes no statement about the quality of the body of knowledge. Thereby, it recognises that the theories, evidence, and measurement methods may be good or poor. It does however allow us to reason about how a contribution to the body of knowledge can be made. This indeed is the objective of a doctoral study: progress in scientific inquiry can be examined by comparing how well we can improve the current accumulation of theories, evidence and measurement methods in a certain domain. For instance, a contribution could be to improve the explanatory power of a theory of a certain phenomenon. We could also add to the body of knowledge by arriving at better evidence or better or more accurate measurements.

How can one achieve such a contribution? You may notice above that the body of knowledge focuses essentially on two concepts and their relationship, as shown in Fig. 2.1.

We can contribute to the body of knowledge in three ways or combinations thereof:

1. **We can improve our explanation of a particular phenomenon.** This can be done by arriving at a better theory for such a phenomenon, or in other words, by extending a theory. For example, research on theories explaining why people accept or reject information technology over time has improved the theory by showing how additional factors (such as habit, emotion or anxiety) add to our initial understanding, which essentially stated that we accept technology when it



**Fig. 2.1** The body of knowledge

is useful and easy to use. In Chap. 3 below, we will return to the question of how we arrive at better theories in more detail.

2. **We can improve our collections of scientific evidence.** For example, we may be able to collect data about a phenomenon where no observations existed to date. A prime example is the famous voyage of Darwin on the Beagle, where he encountered and systematically described many previously unknown species of plants and animals. This evidence in turn allowed him and other scholars to refine their theories about plants and animals. In fact, it laid the groundwork for a whole new theory, the theory of evolution. Arriving at this theory was only possible because firstly systematic statements about observable facts were created through careful exploration and observation. We return to methods of observation later in this book (in Chap. 5).
3. **We can better our methods for collecting observations in relation to theory.** Again, let me give you an example from the history of science. One of the most important contributions Galileo Galilei made was through the improvements he invented for telescopes, which initially were invented by Hans Lippershey. Galileo made a telescope with about  $3\times$  magnification and later made improved versions with up to about  $30\times$  magnification.

Through a Galilean telescope the observer could see magnified, upright images of the earth or the sky, a greatly improved measurement compared to previous instruments, which largely relied on the naked eye. It was only through these refined instruments that Galileo noted how the positions of some “stars” relative to Jupiter were changing in a way that would have been inexplicable if they had been fixed stars (the current theory at the time). For one thing, he discovered that the “fixed stars” at some points in time were hidden behind Jupiter.

The improved measurements of the satellites of Jupiter created a revolution in astronomy that reverberates to this day: a planet with smaller planets orbiting it did not conform to the principles of Aristotelian Cosmology – the then prevalent astronomical theory, which held that all heavenly bodies should circle the Earth.<sup>3</sup> Still, we know now that Galileo was right and that this breakthrough was possible because he initially did not refine the theory or the observations but instead improved our ability to measure relevant phenomena.<sup>4</sup>

The above examples are meant to illustrate the manifold ways in which scientific progress can be achieved. Yet, it does not answer the question of how recognisable progress can be achieved. To that end, we need to look at the process of scientific inquiry and the postulates of the scientific method.

## 2.2 The Scientific Method

In Chap. 1, we ascertained that in doctoral research we are asked to learn and execute studies that comply with two key principles of scientific research, namely, the research work contributes to a body of knowledge and the research work conforms to the scientific method.

We then illustrated several ways in which one can contribute to the body of knowledge through the scientific output created. Let us now turn to the notion of the scientific method. The scientific method describes a body of techniques and principles for investigating real-world phenomena with the view to adding to the body of knowledge.

Above we argued ambiguity in the connotation of the term “research” and that a doctoral program is about one type of research only, the class of scientific research. For research to be called scientific, the scientific method postulates that the inquiry must be based on gathering empirical and measurable evidence subject to specific principles of reasoning.

Although research procedures vary from one field of inquiry to another, the scientific method provides us with some common features that distinguish scientific inquiry from other methods of obtaining knowledge. Most notably, scientific inquiry is generally intended to be *as objective as possible*, to reduce biased

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<sup>3</sup> We should note here that Galileo initially endured significant resistance against his findings, because his measurement was not trusted as a scientific instrument. It took decades of *replication* (another scientific principle), until his findings were confirmed to the extent that they were trusted as valid observational evidence.

<sup>4</sup> Refining measurements is still very much prevalent to date. To note just one example: the improvements in neuroscientific measurement methods such as fMRI scanners provide much more precise measurement of brain activities than any other measurement instrument used in cognitive psychology to date.

interpretations of results and to reduce dependency and partiality of the research team or any interpreter of the findings.

To ensure as much objectivity in research as possible, several principles are provided by the scientific method as a sort of checklist:

### 1. **Replicability**

Replicability is a term that characterises the extent to which research procedures are repeatable. The principle states that the procedures by which research outputs are created should be conducted and documented in a manner that allows others outside the research team to independently repeat the procedures and obtain similar, if not identical, results. Put in simple terms, the question to ask is “if I repeated your research based on how you conducted it and described it to me, would I get to the same results?” Replicability relies to an extent on the expectation to carefully and in great detail, document, archive, and share findings, data, measurements, and methodologies so they are available for careful scrutiny by other scientists, giving them the opportunity to verify results by attempting to reproduce them.

### 2. **Independence**

Independence is closely related to reliability. It concerns the extent to which the research conduct is impartial and freed from any subjective judgment or other bias stemming from the researcher or research team itself. Independence is sometimes easier to achieve (when working with factual, objective, precise data) and sometimes harder (in interpretive research where we attempt to explain a phenomenon by interpreting available sentiments or statements about the phenomenon from participants). As we will discuss in Chap. 5 below, different research methods are challenged by and deal with independence in different manners; for example, in some interpretive research teams of external coders are used to verify the impartiality of one’s subjective judgment.

### 3. **Precision**

The precision principle states that in all scientific research the concepts, constructs, and measurements should be as carefully and precisely defined as possible to allow others to use, apply, and challenge the definitions, concepts, and results in their own work. I noted above that especially in the social sciences many important concepts like happiness, satisfaction, joy, anxiety, and so forth are in essence very hard to define and carry many connotations. A precise definition and measurement is therefore critical to ensuring that the interpretation of the chosen research concept can be comprehended by others, used, or perhaps even challenged.

### 4. **Falsification**

Falsification is probably the most important principle in scientific research. It originates from the thinking of the philosopher Karl Popper [131] who argued comprehensively that it is logically impossible to conclusively prove theories in scientific research. Instead, scientific theories can only be disproven, i.e., falsified. In other words, falsifiability describes the logical possibility than an assertion, hypothesis, or theory can be contradicted by an observation or other

outcome of a scientific study or experiment. Importantly, that a theory is “falsifiable” does not mean it is actually false; rather that if it is false then some observation or experiment will produce a reproducible and independently created result that is in conflict with it.

The falsification argument has at least two important implications. First, it draws a clear boundary around the possibilities of scientific research: our theories are sets of suggested explanations that are assumed to be true because the evidence collected to date does not state otherwise. Newton sat under the apple tree and apples were falling on his head, which allegedly gave him inspiration about a theory of gravity. As per that theory, apples fall to the ground because of gravitational forces exerted by the earth’s core that pull them towards the ground. Following this anecdote the question is: does the theory conclusively and irreversibly predict that all apples will always fall to the ground? No, it cannot. There is no logical way to prove conclusively that apples will continue to fall to the ground even if all apples to date have done so. Instead, if we were to find an apple that, say, scoots off into the sky we would have found evidence that is contrary to the theoretical prediction and in turn, we would have falsified Newton’s theory. Second, falsification also implies an important criterion for the theories that are created as scientific output: a good scientific theory is one that can be falsified (i.e., a falsifiable theory). This principle implies that theories must be stated in a way that they can, hypothetically, be disproven. If we do not define a theory in a way that allows us or others to disprove the theory using carefully measured observations then we have not complied with the scientific method and in turn have not offered a scientific contribution to the body of knowledge.

For example, the assertion that “all swans are white” is falsifiable, because it is logically possible that a swan can be found that is not white. By contrast, consider the example of the Rain Dance Ceremony theory:

If you perform the Rain Dance Ceremony and all the participants are pure of heart, it will rain the next day.

Proposing this theory is not a scientific undertaking because this theory is not falsifiable: If you perform the ceremony and it rains, the theory is confirmed. If you perform the ceremony and it doesn’t rain, it would suggest that one of the participants was not pure of heart, and again the theory is confirmed. Unfortunately, being pure of heart is not a property that we can precisely, reliably, and independently measure and therefore we cannot possibly create a scenario in which we could disprove our Rain Dance Ceremony theory.

The idea behind the scientific method is not to accredit or discredit research endeavours of any sort. It is, however, used to separate scientific research from other fields of research. A common example is that of theology, which is not a science because its inquiries do not conform to the principles of the scientific method. For one thing, the principle of falsifiability is violated because phenomena such as divine intervention cannot independently be tested or verified. Similarly, humanities, literature, and law are not sciences in that their work relies heavily on

the ability to interpret complex material in a sense-making process, a procedure that, by its very nature, is not independently repeatable as it is subject to the individual performing the inquiry.<sup>5</sup>

## 2.3 Essential Concepts in Information Systems Research

One of the most frequently occurring problems that I encounter with doctoral students is that, simply put, our conversations are hampered by us using “standard” research concepts and terms in different denotations. In a way, the problem is not so much that the theoretical construct, operationalisations, measurements, and observations we are discussing are not precise enough; rather that our definitions of terms such as construct, concept, variable, etc. differ.

To resolve this problem, let us have a close look at the way that I define some essential concepts for usage in this book. I have tried to relate them in Fig. 2.2.

First, we need to define the term *concept*. A concept describes an abstract or general idea inferred or derived from specific instances that we perceive in the real world. Concepts are thus mental representations that we develop, typically based on experience. Concepts can be of real phenomena (dogs, clouds, pain) as well as of some latent phenomena that we can agree upon (truth, beauty, prejudice, usefulness, value, and so forth).

We use concepts as a language mechanism all the time to describe general properties or characteristics that we ascribe to certain things or phenomena. For example, we use the concept of weight to describe the force of gravity on objects. Weight is a general property that applies to all tangible things in the real world. But we can also use the same concept, weight, to illustrate the psychological state of someone experiencing stress, tension, and anxiety as we do when we refer to the “weight on their shoulders”. We sometimes also develop new concepts to describe a new or newly discovered property. Emotional intelligence, for example, is a concept that purports to describe our self-perceived ability to identify, assess, and control the emotions of oneself, of others, and of groups. This concept has gained some prominence in a debate regarding whether it is a personality trait or form of intelligence not accounted for in currently prevalent theories of intelligence or personality (which, by the way, are also concepts).

As abstract units of meaning, concepts play a key role in the development and testing of scientific theories. They give us a vocabulary to reason about some real-world phenomena (or the linkage between real world phenomena, as shown in Fig. 2.2) and a means to ascribe characteristics or properties to those phenomena and their relationships. Concepts can be linked to one another via propositions – suggested tentative or conjectured relationships between two or more concepts

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<sup>5</sup> Note again that these statements do not qualify these research inquiries but are merely used to distinguish different strands of research.



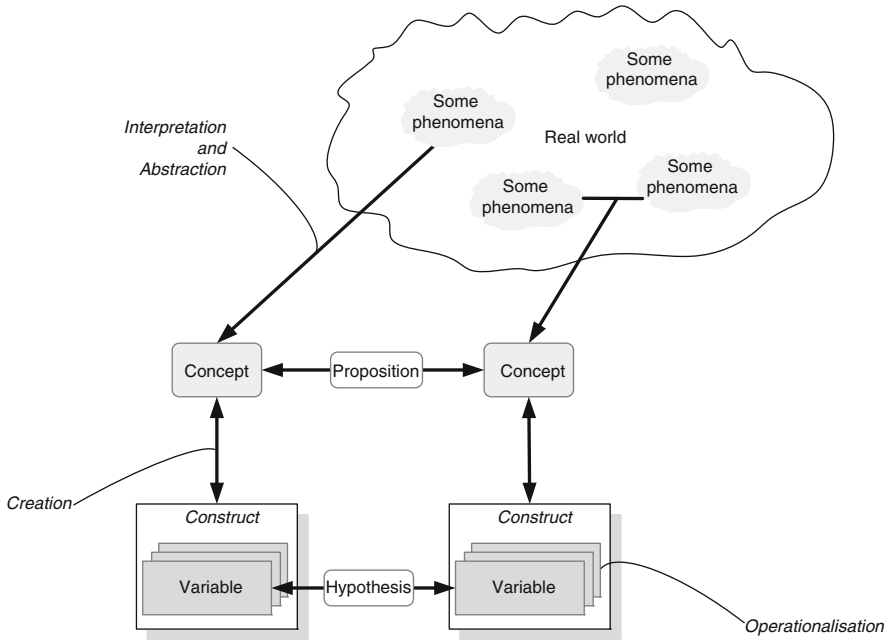


Fig. 2.2 Essential concepts in the research process

that are stated in a declarative manner, more intelligence leads to better decisions, for example.

Note the key words *suggestion*, *tentativeness*, and *conjecture* that I apply to the notion of a proposition. These terms characterise the fact that propositions are proposals for an explanation about how phenomena are related. Whether or not the propositions hold true is an entirely different question and typically, an empirical one that we need to answer carefully through dedicated research methods.

The problem with concepts is that many of the *phenomena* we are interested in such as satisfaction, empathy, intelligence, anxiety, skill, and so forth, are fuzzy and imprecise. This is mostly because most phenomena of interest are not directly observable, and instead rather abstract and difficult to capture, define, or visualise. It is also because in the social sciences we often are concerned with understanding behaviours, processes, and experiences as they relate to “information technology in use”.

For example, take the simple proposition “education increases income”. The concepts of education and income are, by definition, abstract and could have many meanings. Conclusively, there are many, potentially unlimited ways in which such a proposition could be tested – and in turn, many different results could be obtained. Therefore, a proposition (also called a conceptual hypothesis) cannot be tested. They need to be converted into an operational hypothesis.

As per Fig. 2.2 above, we note that hypotheses are suggested linkages between constructs. *Constructs* are operationalised concepts, where we attempt to take the

abstract meaning of a concept such as education, for example, and operationalise it to something in the real world that can be measured. The concept education, for instance, could be operationalised as “highest degree earned”, which in turn could be measured by ascertaining what type of course (high school, under-graduate, post-graduate, etcetera) a person had completed. Income could be operationalised as the construct “Yearly Salary”, which can be measured by comparing annual salary figures before tax in US Dollars. Importantly, we can see how “income” is a fuzzy concept as it remains unclear which specific meaning we apply to this notion (are we talking about annual or monthly income? Before or after taxes?). A construct by contrast is specified to the required level of precision; in the case of our example, it might be annual gross salary.

A construct is thus the creation of an operationalisation of a concept in a way that we can define it in terms of how we can measure the construct. In this process, we attempt to describe fuzzy and imprecise concepts in terms of their constituent components that are defined in precise terms. By doing so, we eliminate *vagueness* (how many centimetres exactly is a “tall” person?) and *ambiguity* (“I purchased a bat” could have many meanings).

This process is a challenging mental procedure. For instance, to operationalise the concept prejudice we would have to ask ourselves “what does prejudice actually mean to us? Are there different kinds of prejudice (race, gender, age, religion)? How could we measure them?”

Depending on the answers chosen we can, generally speaking, create uni- or multi-dimensional constructs. *Uni-dimensional constructs* are composed of only one underlying dimension like weight, height, speed, and so forth. In turn, these uni-dimensional constructs can be measured through one *variable*. A variable is thus the empirical indicator that allows us to approximate the underlying latent construct. You can also call a variable a measurable representation or manifestation of a latent construct in the real world. For example, when we define the concept “weight” as the construct describing the force on an object due to gravity, then we can define a measurement variable that specifies different levels of weight, for instance, using a metric scale (in kilograms). Because weight is a relatively simple, uni-dimensional construct, there is typically not a need to define multiple measurement variables. This is also the case because even if you measure a person’s weight in kilograms and pounds you would obtain the same result since the scales are equivalent. Other good examples for uni-dimensional constructs include age, gender, time, income, and others.

Most constructs, however, are more complex. By complex, I mean that they are composed in a multi-dimensional set of underlying concepts. Intelligence, for example, can hardly be measured by one variable only, because we understand this concept to pertain to abilities for abstract thought, understanding, communication, reasoning, learning, planning, problem solving and others, including emotional intelligence as mentioned above. Such constructs we call *multi-dimensional constructs* because they possess several underlying dimensions, all of which are relevant to our understanding and use of the construct and all of which we consequently need to measure separately through dedicated variables. Taking the example

of intelligence again, we now see the reason for the existence of the IQ (intelligence quotient) score, which is the standardised outcome of a complex test that contains measurement variables to ascertain the levels of intelligence of individuals alongside a number of ability dimensions such as abstract thought, communication, creativity, learning, memory, problem solving, reasoning, visual processing, and others.

Thus, we use variables as measurable representations of constructs that create precise operationalisation of concepts that in turn present a mental abstraction of some property of some phenomenon in the real world. By doing so, we can also speculate about linkages of phenomena not only in conceptual propositions but also in so-called operationalised hypotheses. A *hypothesis* is the empirical formulation of a proposition that is characterised as a testable relationship between two or more variables. Hypotheses need to be formulated such that they are directly empirically testable and such that they allow for precise reasoning about the underlying proposition they represent. For example, “highest degree earned is related to annual gross salary” is what we call a *weak hypothesis*, because it fails to specify *directionality* (does the earning of a degree cause an increase or decrease in annual gross salary?) or *causality* (does annual gross salary cause a specific degree or vice versa?). A *strong hypothesis*, by contrast, would be the statement “the higher the degree earned, the more annual gross salary will be earned”. As this example shows, hypotheses need to clearly specify directionality as well as causality by clearly delineating which variables lead to which effect on which other variable. A statement “Europeans earn high annual gross salaries”, for example, is not a hypothesis because it does not specify a directional/causal relationship between two variables. In turn, we cannot collect meaningful data to evaluate the hypothesis – which in turn violates the principle of falsification.

## 2.4 Further Reading

As alluded above, I found Alan Chalmers’ introductory book on the philosophy of science an immensely worthwhile read for understanding common principles of good scientific inquiry [33]. Karl Popper’s seminal article on “The logic of scientific discovery” is also a good and more detailed follow-up to the simplistic explanations I gave about falsification [131]. For a more critical view about the principles of scientific method and their limitations, you can consult Paul Feyerabend’s “Against Method” [63].

A good introduction to essential concepts in IS research I found to be Anol Bhattacherjee’s book on social science research [20]. Similar term definitions can also be found in other introductory textbooks such as those by Paul Creswell [40] or Paul Reynolds [141]. Finally, a key paper that defines constructs and operationalisations as elements of a nomonological net (see Chap. 4) is that of Lee Cronbach and Paul Meehl [41].



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