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Panel: A call for action in tackling environmental sustainability through green information technologies and systems

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SCIENTIFIC PROGRESS OF DESIGN RESEARCH ARTEFACTS

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Abstract

In parallel to widely accepted behavioural research, Design Research (DR) has emerged in Information Systems. Nonetheless, the debate about the scientificity of DR is still ongoing. In the course of this debate, the role of scientific progress has hardly been discussed. But, doubtlessly, scientific progress is regarded as one of the main aims of science; science can even be defined by scientific progress. Philosophy of science has therefore developed a variety of concepts for scientific progress mostly adapted to explanatory and/or predictive theories. Nonetheless, the output of DR differs from those theories; therefore, concepts developed cannot be applied to DR without further ado. In this paper, we propose a first concept for scientific progress of DR artefacts. Because of the complexity of the field we firstly restrict to the research question: What is scientific progress of DR artefacts? Progress is commonly defined as a transition from step A to B whereby B is “better” than A. The aim of our research is to identify criteria for concretizing what is “better” in the context of DR and to define criteria of progressive DR artefacts. We thereby identified the following five criteria: utility, internal consistency, external consistency, scope, and efficiency.

Keywords: Design Science, Design Research, Design Theory, Scientific Progress.

1 THE IMPORTANCE OF SCIENTIFIC PROGRESS TO DESIGN SCIENCE

In parallel to widely accepted positivistic research approaches, design research (DR) has emerged in Information Systems (IS) Research (Hevner et al. 2004) and in other management sciences, e. g. organisational science (van Aken 2004; Romme 2003; Romme & Endenburg 2006).[1] In ISR, a variety of articles describing and reflecting the construction and evaluation of concrete DR artefacts have been published.[2] In parallel to the construction of concrete artefacts, authors also reflected the nature of design oriented research as well as the construction and evaluation of DR artefacts in general.[3]

Although many advances have been done in Design Science (DS) in IS, the debate on the scientificity of DR is still ongoing. In the course of this debate, the role of scientific progress has hardly been discussed. However, scientific progress is regarded as one of the main aims of science; science can even be defined by scientific progress.[4] Philosophy of science has developed a variety of concepts for scientific progress. But, in most cases, they were adapted to theories in natural sciences, later also to theories in other disciplines (e. g. social sciences). Nonetheless, the output of DR differs from explanatory and predictive theories (Gregor 2006; Romme 2003). Therefore, concepts developed in philosophy of science referring to "traditional theories"[5] cannot be applied to DR artefacts without further ado.

The aim of this paper is to transfer results of the discussion about scientific progress led in Philosophy of Science to the field of DS in IS. This is doubtlessly a complex enterprise. Yet, there has not been conducted much research on scientific progress in DR; consequently, this paper can only be a first approach. At the beginning of such a research, it is necessary to advance stepwise. The aim of this paper is to develop a set of criteria of progress of DR artefacts. This research aim concerns the ontological understanding of DR artefacts. Gregor and Jones (2007) make a seminal contribution by synthesising the ontological understanding of design research artefacts in a broad literature review. We therefore take their work as a starting point for our investigations.

In order to transfer results from philosophy referring to traditional theories to DR artefacts, we firstly trace the complex discussion of scientific progress in philosophy of science briefly. Secondly, we describe the anatomy of DR theories in order to understand differences to traditional theories. Thirdly, we transfer concepts from philosophy of science referring to traditional theories to DR artefacts and identify criteria of progress of DR artefacts. Finally, we summarise the criteria identified and show the necessity of further research.

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[1] Different authors in management sciences and information systems have a different understanding of what they mean by "design". Some authors emphasise on aesthetical aspects and on creativity (Ehn & Malmborg 1998; Stolterman 2008) whereas others emphasise on utility and an engineering-like construction (van Aken 2004; Hevner et al. 2004; Romme 2003). In this paper, we clearly emphasise on the utility of the artifact and an engineering-like construction process.

[2] An overview of the articles published at the Design Science Research in Information Systems Conference (DESRIST) is summarised by Bucher & Winter (2008, table 1 and table 2).

[3] According to Winter (2008, p. 471), in this article, we call the concrete construction of design research artefacts "Design Research", the reflection on the nature of design research artefacts and on their construction and evaluation in general "Design Science".

[4] Kuhn (1970, p. 162) asks the rhetorical question: "Does a field make progress because it is a science, or is it a science because it makes progress?"

[5] In the following, we call descriptive, explanatory, and predictive theories "traditional" in order to demarcate them from design theories (Gregor 2006).

2 SCIENTIFIC PROGRESS IN PHILOSOPHY OF SCIENCE[6]

Progressivity of science has always been discussed in philosophy of science. Early works on the subject were already published in the 19th century, e. g. by William Whewell (Losee 2004, pp. 7-27). As always in philosophy, the discussion of scientific progress is multifarious. However, in the entire discourse there is one consensus: Scientific progress is a normative concept. A step from stage *A* to *B* constitutes progress if *B* is better than *A* in respect to some standards or criteria (Bird 2008). Object of discussion is the nature of such standards or criteria.

It is impossible to entirely summarise that broad discussion in this short article. Instead, we restrict ourselves to three major schools in philosophy of science whose concept of scientific progress influenced other philosophers of science significantly (Kaiser 1991, p. 12): the Logical Empiricism by the philosophers of the Vienna Circle, the Critical Rationalism by Popper, and the descriptive approach to philosophy of science by Kuhn. Finally, we propose how to synthesise some of the concepts presented by referring to Scientific Structuralism.

2.1 Logical Empiricism

The emergence of the Logical Empiricism is often said to be the beginning of modern philosophy of science. The concept of science of the Logical Empiricism was developed by the philosophers of the Vienna Circle since the 1920s. The seminal contributions of Logical Empiricism to philosophy of science in general, and to the subject of scientific progress in particular, were a starting point for the discussion by many philosophers later-on. Thereby, the Deductive-Nomological model for scientific explanations by Hempel and Oppenheim (1948) is central for the conceptualisation of science by Logical Empiricism. A scientific explanation consists of an explanans and an explanandum logically deducted from the explanans. The explanandum consists of at least one statement of antecedent conditions and at least one general law. The explanandum is a description of the empirical phenomenon to be explained, cf. Figure 1 (Hempel & Oppenheim 1948, p. 138).

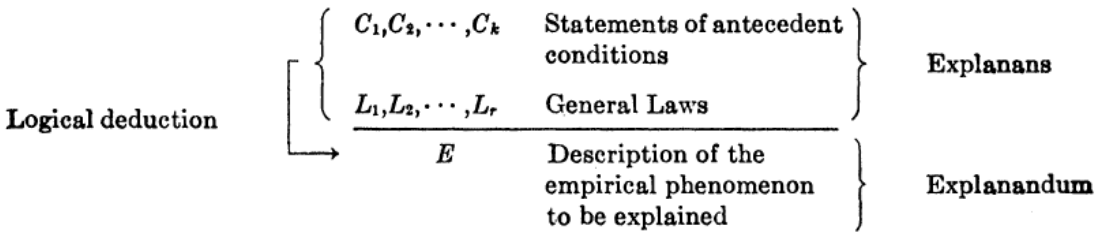

Figure 1. The Deductive-Nomological model for scientific explanations (Hempel & Oppenheim 1948, p. 138)

The scientific explanation by Hempel and Oppenheim can explain concrete phenomena[7], but also general laws. For instance, the general law L2 “All copper expands when heated.” (explanandum) can be explained by the more general law L1 “All metals expand when heated.” in conjunction with the antecedent condition “Copper is a metal.” (explanans). In the conception of logical empiricism, law L1 is progressive in comparison to L2 because it does not only explain all phenomena L2 can explain, but also phenomena that cannot be explained by L2, e. g. “Tin is a metal”, “This is tin.”, “Therefore, this

[6] The argumentation of subsections 2.1 and 2.2 refers to Craig Dilworth’s introductory book “Scientific Progress” (Dilworth 2007).

[7] An example for explaining a concrete phenomenon is: “All copper expands when heated.” (general law), “This is copper.” (statement of antecedent condition), “Therefore, this expands when heated.” (explanandum).

tin expands when heated." (Dilworth 2007, p. 21). Hempel (1962, p. 100 f.) gives the following example from history of science: "[T]he uniformity expressed by Galileo's law for free fall can be explained by deduction from the general laws of mechanics and Newton's law of gravitation, in conjunction with statements specifying the mass and radius of the earth."

The concept of scientific progress by the Logical Empiricism is based on exactly that deduction of one less comprehensive theory from another more comprehensive one: the more comprehensive theory is then progressive compared to the less comprehensive one. This concept is based on the assumption of a continuity of scientific knowledge, such that proceeding theories logically entail their predecessors.

2.2 Critical Rationalism

The Popperian concept of scientific progress fundamentally differs from that of Logical Empiricism in exactly this point. Popper does not emphasise on continuity, but on contradiction. In response to the Logical Empiricism, he states: "[F]rom a logical point of view, Newton's theory, strictly speaking, contradicts both Galileo's and Kepler's. […] For this reason it is impossible to derive Newton's theory from either Galileo's or Kepler's or both, whether by deduction or induction" (Popper 1973, p. 198).

Whereas Logical Positivism is able to distinguish between more and less progressive theories, but not to explain conflicts of theories Popper's concept can explain theory conflict; but, in a first step, it fails to distinguish more progressive theories from less progressive ones (Dilworth 2007, p. 26). As a concept of scientific progress is central for each concept of science, Popper claims two criteria that make a theory more progressive in comparison to another one: their content and their verisimilitude.

Popper's "study of the *content* of a theory […] was based on the simple and obvious idea that the informative content of the *conjunction*, *ab*, […] will always be greater than, or at least equal to, that of any of its components. Let *a* be the statement 'It will rain on Friday'; *b* the statement 'It will be fine on Saturday'; and *ab* the statement 'It will rain on Friday and it will be fine on Saturday': it is then obvious that the informative content of this last statement, the conjunction *ab*, will exceed that of its component *a* and also that of its component *b*" (Popper 1963, pp. 217-218). For instance, according to Popper, Keppler's or Galileo's theory is logically less strong and testable compared to Newton's one; therefore, Newton's theory has a richer content and is progressive in relation to Keppler's or Galileo's one. Moreover, the content of a theory is inverse to its probability. Obviously, the probability of *ab* is less than the probability of *a* or the probability of *b*. Consequently, a less probable theory has a greater content and is therefore ceteris paribus (c. p.) progressive (Popper 1963, p. 218).

The second Popperian criterion for scientific progress, the verisimilitude of a theory, can be described by its nearness to the truth. According to Popper, truth of a theory cannot be attained, but rather approached. A theory *a* is closer to truth than a theory *b* if *a* has more true consequences and less false ones than *b* (Bird 2008).

2.3 Kuhn's historical view

Whereas Logical Empiricism and Critical Rationalism have a prescriptive concept of science, i. e. they state how science *should* be, Kuhn develops a descriptive approach by analysing history of science, i. e. he describes how science factually *is*. Especially Feyerabend, seizing many suggestions by Kuhn, strongly criticises Popper's emphasis on falsification and argues that falsification has nearly never been the reason for rejecting a theory (Feyerabend 1989, pp. 250-259).

Instead, Kuhn's (1970) concept of Scientific Revolution is said to better describe science as it is. According to that concept, each scientific discipline starts in a pre-paradigmatic phase. There, its members even do not agree on fundamental aspects, e. g. they do not speak a common language. When such different fundaments are harmonised usually a phase of Normal Science begins. Normal science is based on a paradigm supported by the research community. Kuhn (1970, pp. 35-42) describes science in such a phase as "puzzle solving": Normal science is often very efficient, but it does not produce revolutionary outcomes. Nevertheless, at some moment, scientists begin to question their common fundamentals, e. g. core theories that are suddenly unable to explain newly detected phenomena. A crisis begins and leads to a scientific revolution. New theories are developed and tested until an appropriate candidate for explaining the newly detected phenomena is agreed on. Then again, a period of normal science begins until a new crisis appears.

After a scientific revolution, it might happen that the new paradigm cannot explain every phenomenon as good as the antecedent one (Kuhn 1970, pp. 99-100). Such a partial regress was called “Kuhn-loss” later-on (Bird 2008). Because of this Kuhn-loss, Kuhn’s understanding of scientific progress is not cumulative – as opposed to Logical Positivism and Critical Rationalism. Kuhn moreover denies any concept of nearness to truth. In his point of view, science develops rather evolutionarily, i. e. science develops like an organism that continuously adapts itself to its environment (Kuhn 1970, pp. 170-173).

Kuhn’s and Feyerabend’s conception of scientific progress is strongly marked by their incommensurability thesis. In everyday speech, “incommensurable” means not to have a common standard of measurement. Kuhn uses this term by referring to theories. His view is that a theory is always evaluated by comparing it to a paradigm. Therefore; the standards of theory evaluation are not permanent because paradigms change; they are not theory-independent because they involve a comparison to a (paradigm) theory; and they are not based on rules because they involve perceived relations of similarity (Bird 2008). Consequently, it is very difficult – if not impossible – to compare two theories.

Kuhn differentiates three types of incommensurability (Bird 2008): methodological incommensurability, observational incommensurability, and semantic incommensurability. Firstly, methodological incommensurability is caused by the fact that theories are always evaluated in reference to a paradigm. Therefore, theories having evolved in two different paradigms are not evaluated on the same basis. Secondly, observational incommensurability is caused by theory-dependency of observation. One basis for Kuhn’s argumentation is the gestalt-switch theory developed by Hanson (1958). Hanson uses the example of a picture called bird-antelope (Hanson 1958, p. 87). Usually, at a first view, the observer of that picture sees a bird. But, when somebody tells the observer that it can also be seen as an antelope, the observer usually begins to see an antelope, too. Hanson concludes our perception to be strongly influenced by our previous knowledge. Kuhn (1970, pp. 113-115) transfers Hanson’s discovery to theories and states that all observation is always conducted in the light of the theories of the accepted paradigm. Therefore, observation depends on theory. Consequently, observations conducted against the background of two paradigms cannot be easily compared with each other. This is called observational incommensurability. Lastly, semantic incommensurability is based on a change of the meaning of theoretical terms when a paradigm changes (Bird 2008). For example, the meaning of the word “mass” has slightly changed when Einstein formulated the theory of relativity. In the Newtonian mechanics, mass is a constant concept – e. g. a skyrocket on earth and on moon were considered to have the same mass. Einstein, in contrast, denies mass to be constant by stating that mass and energy are equivalent to each other ($E=mc^2$). Such slight changes in the meaning of theoretical terms also make comparisons of two theories difficult.

Despite all difficulties revealed by Kuhn, he identifies five characteristics “of a good theory” (Kuhn 1977, p. 321):

> “First, a theory should be accurate: within its domain, that is, consequences deducible from a theory should be in demonstrated agreement with the results of existing experiments and observations. Second, a theory should be consistent, not only internally or with itself, but also with other currently accepted theories applicable to related aspects of nature. Third, it should have broad scope: in particular, a theory's consequences should extend far beyond the particular observations, laws, or subtheories it was initially designed to explain. Fourth, and closely related, it should be simple, bringing order to phenomena that in its absence would be individually isolated and, as a set, confused. Fifth – a somewhat less standard item, but one of special importance to actual scientific decisions – a theory should be fruitful of new research findings: it should, that is, disclose new phe-

nomena or previously unnoted relationships among those already known"(Kuhn 1977, pp. 321-322).

Kuhn (1977, p. 322) later-on explains that accuracy is important, but would be insufficient as a single criterion. Accuracy comprises explanatory and predictive power.

Nevertheless, two critical remarks referring to these criteria are made by Kuhn himself. Firstly, they are individually imprecise: individuals might differ about their application to concrete cases. Secondly, "when deployed together, they repeatedly prove to conflict with one another" (Kuhn 1977, p. 322).

2.4 Criteria for Scientific Progress

The three important approaches in philosophy of science presented in the preceding sections can hardly be harmonized. Philosophers of science often call the three positions the "Bermuda Triangle of Philosophy of Science". If one tries to take a position inside that triangle, i.e. to harmonize aspects of at least two of the three positions, he will be caught by a vortex he cannot escape from any more (Kaiser 1991, p. 12). Being aware of this problem, we do not even try to harmonize the three positions - this task should be undertaken by philosophy.

Nonetheless, in order to be able to transfer the results of the discussion in philosophy of science to IS design theories, it is necessary to summarize the three approaches. We propose a set of criteria relevant for the discussion on scientific progress. The summary is illustrated in Table 1.

	Criterion: Theory T1 is ceteris paribus progressive relative to theory T2 if …	**Logical Empiricism**	**Critical Rationalism**	**Kuhn**
C1	… T2 is logically deducible from T1	X	cf. C2	cf. C6
C2	… T1 has a greater content than T2	cf. C1	X	cf. C4, C6
C3	… T1 is closer to truth than T2		X	cf. C4
C4	… T1 is more accurate than T2, i.e. T1 has a greater explanatory power than T2 or T1 has a greater predictive power than T2		cf. C2, C3	X
C5	… T1 is more consistent with itself than T2 or T1 is more consistent with other theories than T2			X
C6	… T1 has a broader scope than T2	cf. C1	cf. C2	X
C7	… T1 is simpler than T2			X
C8	… T1 is more fruitful of new research findings than T2			X

Table 1. Criteria for Scientific Progress in Philosophy of Science

Some of the criteria listed in Table 1 are redundant. The criterion C1 stemming from logical empiricism, i.e. the logical deducibility, is strongly based on an idea of continuity in science that is denied by the two other authors. Nonetheless, if a theory T_2 is logically deducible from a theory T_1, the scope of theory T_1 is broader than the scope (C6) of T_2 (or at least as broad as it). Moreover, the special notion of "content" formed by Popper (1973) implies that a theory with a higher content is more accurate than another with a lesser one. Therefore, there is also a relationship between content and accuracy.

The closeness to truth (C*3*) has some similarities to the accuracy of the theory. Kuhn avoids the term of truth in order to be independent of strong ontological and epistemological positions. The term "truth", at least if following the correspondence theory of truth, necessitates a position of a scientific realist. Kuhn does not explicitly take such a realist position. Instead, he emphasizes the explanatory and predictive power of theories and thereby adopts an instrumentalist view. Closeness to truth for a scientific realist is accuracy for a scientific instrumentalist.

We can conclude that the criteria mentioned by Kuhn (1977, pp. 321-322) are – as he states himself – exhaustive in the sense that they cover the criteria we extracted from Logical Empiricism and from Critical Rationalism. Consequently, we will use the following criteria for our further argumentation: accuracy, internal consistency, external consistency, scope, simplicity, and fruitfulness of new research findings.

3 THE NATURE OF DESIGN RESEARCH THEORY

In order to be able to transfer concepts of scientific progress developed for theories in natural sciences to IS DS, the differences between the outcomes of natural sciences and those of design research should be explained. Many publications in DS dealt with epistemological aspects of DR, e. g. with epistemological aspects of the construction and evaluation of design research. Compared to research about epistemological aspects, ontological aspects of design research in IS have been neglected. Nonetheless, in recent years, some authors emphasised on ontological aspects of DR. A seminal article on the “Anatomy of a Design Theory” was published by Gregor and Jones (2007) in which they described core components of an IS design theory.

3.1 On the output of DR: Design Research Artefacts or Design Theories?

Gregor and Jones (2007) write about theories as main outcome of DR. Up to now, there is no consensus whether DR should theorise (e. g. Hevner et al. 2004; Kuechler & Vaishnavi 2008a; Kuechler & Vaishnavi 2008b; Venable 2006; Walls & Widmeyer & El Sawy 1992) or not (e. g. March & Smith 1995). The proponents argue that “[d]eveloping theory is what we are meant to do as academic researchers […]. Theories are practical because they allow knowledge to be accumulated in a systematic manner and this accumulated knowledge enlightens professional practice” (Gregor 2006, p. 613). Most authors understand design theory as a “utility theory” (Venable 2006) prescribing “how a design process can be carried out in a way which is both effective and feasible” (Walls & Widmeyer & El Sawy 1992). A design theory is a mean to communicate, justify, and develop knowledge in DS cumulatively (Gregor & Jones 2007).

In our paper, we clearly argue for theorising in DR. A synthesis of design knowledge in theories helps to compare results and makes it easier to proof scientific progress, as we will see later-on. Nonetheless, Frank’s (2006) approach is very helpful because it allows us to take a second perspective on design research.

3.2 Components of a Design Theory according to Gregor and Jones (2007)

Gregor and Jones (2007) detail the anatomy of a design theory. Their publication is thereby oriented at a paper published by Walls et al. (1992). The core elements of a design theory identified by Gregor and Jones (2007, p. 322) are listed in Table 2 and explained in the following:

(1) **Purpose and scope** are the characteristic elements of a design theory. Whereas the scope is also relevant for “traditional theories” the purpose is specific to design theories as they are “utility theories” (Venable 2006).

(2) **Constructs** represent the entities of interest in the design theory. Frank (2006) also emphasises on the language the artefact is represented in; he thereby differentiates formal, semi-formal, and natural languages. Constructs are also elements of traditional theories as Dubin (1978) states.

Component	Description
Core components	
1) Purpose and scope (the causa finalis)	"What the system is for," the set of meta-requirements or goals that specifies the type of artefact to which the theory applies and in conjunction also defines the scope, or boundaries, of the theory.
2) Constructs (the causa materialis)	Representations of the entities of interest in the theory.
3) Principle of form and function (the causa formalis)	The abstract "blueprint" or architecture that describes an IS artefact, either product or method/intervention.
4) Artefact mutability	The changes in state of the artefact anticipated in the theory, that is, what degree of artefact change is encompassed by the theory.
5) Testable propositions	Truth statements about the design theory.
6) Justificatory knowledge	The underlying knowledge or theory from the natural or social or design sciences that gives a basis and explanation for the design (kernel theories).
Additional components	
7) Principles of implementation (the causa efficiens)	A description of processes for implementing the theory (either product or method) in specific contexts.
8) Expository instantiation	A physical implementation of the artefact that can assist in representing the theory both as an expository device and for purposes of testing.

Table 2: Components of an IS Design Theory (Gregor & Jones 2007, p. 322)

(3) **Principles of form and function** constitute the architecture of an IS artefact. Principles of form and function also exist for traditional theories: Dubin (1978) refers to "laws of interaction" in reference to traditional theories.

(4) The **artefact mutability** refers to changes in the state of the artefact anticipated in the theory, e. g. suggestions for improving the approach in further works. For traditional theories, there is no equivalent to artefact mutability.

(5) **Testable propositions** are truth statements about the design theory. They are a central element of traditional theories; Dubin (Dubin 1978) names them simply "propositions".

(6) **Justificatory knowledge** is the underlying knowledge or theory from natural or social sciences. Frank (2006) differentiates a variety of justification methods depending on different underlying concepts of truth: correspondence theory of truth, coherence theory of truth, and consensus theory of truth. For each of them, he mentions at least one validation method: for correspondence theory of truth experiment, field study, or case study; for coherence theory literature analysis; and for consensus theory of truth (virtual) discourse according to Habermas (1984). Dubin (1978) does not mention an equivalent element for traditional theories. According to Gregor and Jones (2007), this is due to the fact that Dubin, being realist, explicitly does not emphasize on explanation.

(7) **Principles of implementation** describe the process for implementing the theory in a specific context. This includes situational adaptation of artefacts (cf. Bucher et al. 2007). For traditional theories, Dubin (1978) does not mention an equivalent.

(8) **Expository instantiations** of the theory are physical implementations of the artefact. Often, they are used for testing the artefact. As well as principles of implementation, Gregor and Jones consider them as optional. Frank (Frank 2006) mentions "prototyping" as one method for justifying the artefact. In traditional theories, hypotheses and empirical indicators are very similar to an expository instantiation (Dubin 1978).

4 CRITERIA OF SCIENTIFIC PROGRESS OF DESIGN THEORIES

After having shortly summarised aspects of scientific progress from philosophy of science in section 2 and structural components of DR artefacts and DR theories respectively in section 3, we now transfer the criteria originally created for explanatory and predictive theories to DS. We thereby take, as a starting point, the five criteria for scientific progress by Kuhn (1977, pp. 322-323) which are, as explained in section 2.4, under some presuppositions exhaustive: accuracy, consistency, scope, simplicity, and fruitfulness of new research findings.

Accuracy of a theory in natural sciences is composed by its explanatory and predictive power. Theories in DS do not aim at explaining or predicting, but at being useful. Design Theories are therefore also called utility theories (Venable 2006).

Nonetheless, utility is mentioned as a component of DR [theory] neither by Frank nor by Gregor and Jones. They both mention the purpose of an artefact. The usefulness of an artefact can be defined as its ability to fulfil its purpose if the purpose itself is useful, i. e. relevant. The testable propositions claimed by Gregor and Jones operationalise the usefulness of the artefact. If the testable propositions are exhaustive, the accuracy of a DR theory corresponds to the truth of its testable propositions.

By **consistency**, Kuhn (1977, pp. 321-322) means both internal and external consistency.

The **internal consistency** of a design theory involves nearly all its components. One necessary internal consistency has already been mentioned: the consistency between testable propositions and the purpose of the artefact. The purpose of the artefact should be its leading property because the identity of an artefact is strongly linked to its purpose. The only component of a design theory which cannot be consistent to its purpose is its scope – both concepts are orthogonal one to another. Moreover, the testable propositions should be consistent to all other components of a design theory. A special role in determining the consistency of an artefact is played by its principles of form and function, i. e. its architecture. They give an overview of the artefact and facilitate internal consistency checks.

By **external consistency**, Kuhn means consistency with “other currently accepted theories applicable to related aspects of nature” (Kuhn 1977, p. 322). A design theory should therefore be consistent to both other accepted IS design theories and behavioural theories in IS. External consistency should be shown by a literature review. For external consistency; Gregor and Jones (2007) identify the design theory component of justificatory knowledge; Frank (2006) mentions adequacy according to the correspondence theory of truth.

The broader the **scope** of a theory the better is the theory. The scope of a theory should not only be mentioned, but it should also be justified. The internal consistency of a theory necessitates that testable propositions are formulated and tested such that the whole scope of the theory is covered.

Simplicity is often claimed as a quality factor of theories. Already, William of Ockham said that entities must not be multiplied beyond necessity. Albert Einstein stated to make everything as simple as possible, but not simpler. Simplicity is related to the explanatory power of theories. A complex explanation might be correct, but also might be that complex that it cannot be understood any more. Both, simplicity and explanatory power lead to understanding. In DS theory, understanding is not the primary goal, but utility. The utility of a DR artefact or of a design theory is only slightly affected when it is complex, but strongly when it is expensive, i. e. inefficient. Therefore, the efficiency of a utility theory is the equivalent to the simplicity of an explanatory theory. Simplicity, however, is still important: An efficient design theory implies its simplicity. As the understanding of the theory is time consuming for the practitioner who wants to apply it, an unnecessarily complex theory is inefficient compared to a simpler one.

The efficiency of a design theory should mainly be shown by formulating and testing propositions that show the efficiency of the artefact. The simplicity of a design theory (in the narrow sense of the word simplicity) mainly refers to the constructs, i. e. the language used, and to the principle of form and function of the artefact, i. e. its architecture.

The **fruitfulness of a design theory for further research** is a criterion that is only mentioned by Kuhn, i. e. neither by Logical Empiricism nor by Critical Rationalism. The fruitfulness for further research is – as Kuhn says himself – compared to the other criteria "a less standard item" (Kuhn 1977, p. 322). Fruitfulness for further research can only be determined in a historical analysis of a theory. Therefore, it is difficult to relate fruitfulness for further research to actual components of a design theory.

In summary, progress is a normative concept and can be defined as a transition from stage *A* to stage *B* whereby *B* is better than *A* in respect to certain criteria (Niiniluoto 2007). In order to identify such criteria for DS, we took five criteria for theories in natural sciences formulated by Kuhn (1977, pp. 322-323) and transferred them to DS. Four of these five criteria could be meaningfully transferred to DS and put in relation to components of a design theory. Some of the criteria changed in meaning. The final quality criteria for a "good" design theory are utility, internal consistency, external consistency, scope, and efficiency.

5 FINAL REFLECTION AND OUTLOOK

Scientific progress is a core aim of science. The subject therefore has been treated by philosophy of science for many years. The evolution from Logical Empiricism whose concept is based upon the relatively naïve assumption of continuity in science over the concept of scientific progress by Critical Rationalism to the historical, i. e. descriptive, view by Kuhn shows not only the complexity and diversity of the subject, but makes us also understand that the question of scientific progress is not even finally solved in philosophy of science.

In this paper, five criteria by Kuhn (1977, pp. 322-323) are applied to the structure of design theory. In summary, a good design theory is useful, internally and externally consistent, it has a broad scope, and its artefact is efficient. A theory *T1* that is better in at least one of these criteria and not worse in another criterion compared to a theory *T2* is progressive in reference to *T2*.

The discussion of the problems related to scientific progress formulated by Kuhn (1970), i. e. the methodological, observational, and semantic incommensurability, have shown that scientific progress is a very complex concept. We can learn from Kuhn that it is important to consider the paradigm in which a theory is formulated. A theory can only be evaluated towards such a paradigm. Therefore, it is necessary to know actual paradigms. In order to detect such paradigms, rigorous historical research is necessary (Mason & McKenney & Copeland 1997). It is arguable whether, in our discipline, we are by now in a phase of normal science or still in a pre-paradigmatic phase. A common language is a fundamental requirement for a discipline in a phase of normal science. Such a common language does not broadly exist. Research about different language communities clearly shows that (Schelp & Winter 2008; Schelp & Winter 2009). Such research is very fruitful for IS because it allows for a better understanding of our research outcomes. Difficulties arising from different paradigms in reference to the discussion of scientific progress in IS DS could not be sufficiently discussed in this article. More research in this field is necessary.

Moreover, the subject of scientific progress was only treated on an ontological level. We proposed a criteria-based definition of scientific progress in DS. Besides research focussing on paradigms IS, at least three more research questions concerning scientific progress in design science follow: Firstly, an epistemological question can be posed: How can we detect scientific progress in DS? The criteria developed are a good basis for answering such a question. Moreover, at least two praxeological questions follow: How can we ameliorate DR processes in order to simplify the detection of scientific progress; are new guidelines in addition to those proposed by Hevner et al. (2004) helpful or even necessary? Lastly, we can ask how to construct artefacts that are progressive.

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