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Design Science Epistemology. A pragmatist inquiry

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Design Science Epistemology

A pragmatist inquiry

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Abstract. This paper contributes to the clarification of a design science epistemology. It presents different epistemic types related to three stages of the design science process: 1) Evaluative and explanatory background knowledge (pre-design knowledge), 2) prospective knowledge with design hypotheses (in-design knowledge) and 3) prescriptive knowledge with design principles (post-design knowledge). The epistemological inquiry adopts a pragmatist approach and is pursued through a review of design science literature and informed by an empirical design case on digital support for social welfare allowances. The clarified design science epistemology shows a diversified epistemological landscape with several epistemic types: evaluative, critical, appreciative, normative, explanatory, prospective, prescriptive, categorial and attributive knowledge. Ways to express these epistemic types have been proposed in principal clauses. Ways of grounding have been clarified for each epistemic type. Proposals are given on how to utilize the design science epistemology in relation to design science process models and publication schemas.

Key words: Design science, design knowledge, epistemology, evaluation, explanation, prescription, pragmatism.

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1 Introduction

1.1 Background

After the articulation of design science (DS) as a legitimate research approach in information systems (March and Smith, 1995; Hevner et al, 2004), there has been a growth of such kind of research. There existed, of course, design-oriented research in information systems (IS) earlier, but those scholars framed their research in other ways. Even after the labeling and promotion of the design science approach in IS, not all such research studies self-identify themselves as design science. In an investigation of the use of design science in digital government, Fedorowicz and Dias (2010) identify that "few digital government studies self-identify as belonging to this research paradigm; others present their technological artifact as a case study without grounding in a common methodology or design science framework or theory" (ibid. p. 6). There is no reason to believe that this situation is restricted to digital government, but appears in many other domains of IS research.

Following the seminal paper of Hevner et al (2004) there has been an intense work conducted by IS scholars of filling the different gaps of this approach; for example process descriptions (e.g.,Peffers et al. 2007), design theorizing (e.g.,Gregor and Jones 2007; Lee et al. 2011), evaluation principles and methods (e.g.,Sonnenberg and vom Brocke 2012; Prat et al. 2015; Venable et al. 2016), relations to similar approaches such as action research (Sein et al. 2011), how to write a DS paper (Gregor and Hevner 2013). There have also been discussions about the paradigmatic roots of design science. Most scholars identify the scientific foundations to come from the seminal work of "the sciences of the artificial" (Simon 1996) and "the science of design" (a chapter in Simon 1996; reprinted as Simon 1988). This means a science of the *artificially designed* as opposed to a science of the *naturally given*. Paradigmatic analyses of the ontology, epistemology, and methodology of design science have been conducted by Gregg et al. (2001), Purao (2002) and Iivari (2007), although these do not make any clear positioning within an established research paradigm. There exist however proposals how to position DS paradigmatically. Niehaves (2007) attempts to position DS within an interpretivist paradigm. Carlsson (2010) attempts to position DS within critical realism. There are several proposals to position DS within a pragmatist paradigm (Hevner et al. 2004; Hevner 2007; Cole et al. 2005; Lee and Nickerson 2010; Goldkuhl 2012ab; Ågerfalk and Wiberg 2018). There exists obviously no consensus within the IS research community about paradigmatic foundations of design science. There exist of course many challenges in DS concerning the practical conduct of designing, since these tasks are demanding as they require imaginative and technical skills. Besides this, design science seems to comprise great challenges and uncertainties concerning its epistemological character. There are uncertainties of what kind of outcomes from DS that is mandatory or just optional. There exist different opinions and claims concerning design science outcomes: A useful artifact, design principles, design theory or kernel theory improvement.

Design science has been contrasted to 'behavioral science' (Hevner et al. 2004). The forerunner of that paper (i.e.,March and Smith 1995) used the corresponding notion of natural science. Classical behavioral science is concerned with what-is, i.e.,giving truthful and abstracted accounts of an *already existing world*. Such an approach produces results (descriptions, explanations) that are epistemologically well established. The idea of DS is to work with what-might-be instead of what-is. The outcomes of design science do not have such a clear epistemological character as behavioral science. Hevner et al. (2004) claim that the corresponding function in DS is utility, instead of truth as it appears in behavioral science. This claim is however about the artifact, which is not an epistemic claim as a truth claim is.

There are several contributions describing the nature of design theory as being prescriptive (Walls et al. 1992; Kuechler and Vaishnavi 2012). Is it so simple that behavioral science operates within epistemic functions of descriptive and explanatory character and design science within prescriptive functions? These epistemological issues need to be further addressed. The need for such efforts is well argued by two of the main actors within the IS DS movement, Gregor and Hevner (2013) who state: "We contend that ongoing confusion and misunderstandings of DSR's central ideas and goals are hindering DSR from having a more striking influence on the IS field. A key problem that underlies this confusion is less than full understanding of how DSR relates to human knowledge." (ibid. p. 338). It is of great importance that IS scholars engaging in design science are aware of fundamental epistemological challenges and discourses in order to avoid naïve and dubious knowledge contributions. Hovorka (2010, p. 24) writes: "To assume-away or to simply ignore the significant debates surrounding the production and validation of knowledge would be a disservice to design science research and reduce its validity as a process of knowledge creation". Barquet et al. (2017, p. 398) have also identified a "relative absence of established ways to develop and communicate knowledge contributions from design-oriented research within information systems". Confer also Niehaves (2007) and Baskerville et al. (2015) about needs for further epistemological clarifications.

There is thus an obvious need for clarification of knowledge types in design science studies. A continued epistemological confusion among DS scholars may obstruct an effective execution of DS studies as well as scholarly discourses on methodological principles. A goal is to have DS researchers well equipped with a set of clearly defined knowledge types in design science.

A note on terminology is needed; what to call this kind of research where design efforts play a decisive role? The terminology is not yet settled and stable in IS and neither outside IS. In IS, there exist labels such as "system development research" (Nunamaker et al. 1991), "design-oriented research" (Barquet et al. 2017; Niehaves 2007; Sjöström and Ågerfalk 2009), "design research" (Cole et al. 2005; Hevner and Chatterjee 2010; Purao 2002), "design science" (Hevner et al. 2004; Iivari 2007; Johannesson and Perjons 2014; Niehaves, 2007), "design science research" (Gregor and Hevner 2013; Hevner et al. 2004; Kuechler and Vaishnavi 2012). Some examples of shifting terminology outside IS are: "research through design" in HCI (Zimmerman and Forlizzi 2014), "design science" in management (van Aken 2004); "design-oriented research" in research methodology (Verschuren and Hartog 2005). I have chosen to use the succinct label 'design science' through this text. This seems also be in accordance with the programmatic statement by Simon (1988; 1996) about the "science of design".

1.2 Purpose and focus

There is a need for an inquiry into the epistemology of design science. Epistemology is concerned with the nature of knowledge, its sources, and justification (Steup 2018). How should we epistemologically characterize the knowledge contributions from design science? The purpose of this paper is to conduct an inquiry into design science epistemology (DSE) in order to arrive at a systematized and more exhaustive account of knowledge contributions that are made *within* and *from* design science studies and the inherent epistemic types of such knowledge contributions. The aim is thus to contribute to a re-conceptualization of design science knowledge contributions by exploring its epistemic functions; i.e.,to arrive at a useful classification of epistemic types in design science studies. Why is this important? The idea of clarifying design science epistemology is 1) to further enhance our understanding of this kind of emergent research approach within IS and 2) to give DS scholars a firm base for conducting and gauging IS DS concerning what kinds of epistemic claims that can and should be raised concerning such research.

Design science in IS can be performed concerning different kinds of artifacts. March and Smith (1995) stated that four kinds of DS outcomes could be designed and studied in design science (constructs, methods, models, instantiations). It is clear that a DS approach has been used in IS research for a magnitude of artifacts and design objects.

Knowledge is needed for how to conduct design research for different types of artifacts. This presented paper will have a clear focus on the development of IT artifacts, IS artifacts, digital artifacts or whatever we call this core phenomenon of IS research. An IT artifact, as being a socio-technical artifact (Silver and Markus 2013), is always embedded in a social practice context (Orlikowski and Iacono 2001). The design and study of such artifacts need to take into account its social practice context. The primary focus, in this paper, is thus IT artifacts as designed objects and the epistemology concerned with this. This means a focus on design as product. This entails also an interest in the epistemic logic of the design process.

This focus has been chosen since it seems most urgent to deal with these epistemological matters for IS design science. It is also important not to blur results from this epistemological inquiry with other possible design objects (as methods and models). Future research should investigate epistemological issues for those other types of artifacts. The presented research here can be one possible source for such research.

2 Research approach

2.1 A pragmatist inquiry on epistemology

This research has been conducted through an inquiry. This notion is here used in its pragmatist sense (Dewey 1910; 1938; Thayer 1981; Cronen 2001). An inquiry starts with the experience of an indeterminate and problematic situation and it ends with a transformed situation into a determinate one. This transformation, of an initial problematic situation into a settled and determinate one, passes through different inquiry stages; problem formulation, proposal formulation, abstract reasoning and testing of proposals (ibid.). The research aim is to arrive at an improved conceptualization of design science epistemology. This means that a conceptual analysis is needed. Prominent design science literature is investigated with an epistemological perspective. The DS literature is studied concerning different knowledge items with the purpose to make their epistemic types explicit.

The inquiry is not restricted to literature analysis and conceptual refinement. The DSE conceptualization has emerged through an alternation between conceptual analysis and empirical work. This author has experiences from several design science studies (Sjöström and Goldkuhl 2009; Goldkuhl and Lind 2010; Goldkuhl 2011; Goldkuhl 2012a; Eriksson and Goldkuhl 2013; Goldkuhl et al. 2015; Goldkuhl 2016). These DS experiences have of course influenced the emergence of this epistemological conceptualization. One empirical case of design research has been selected for use in this paper. This case has been used as an important vehicle in this inquiry. It has been used in a generative fashion for analysis, illustration, and formulation of design science epistemic types. This case has also been used as a means for testing the adequacy and applicability of the proposed DS epistemic types.

2.2 Epistemic type

The central concept in this inquiry is *epistemic type*. Different possible knowledge items within design science are epistemologically characterized, i.e.,different epistemic types are assigned to the identified DS knowledge items. This work with epistemic types is mainly inspired by the communicative action theory of Habermas (1984). This theory builds on a rational view of knowledge and its validity. To claim the validity of knowledge means that good reasons as arguments are presented in order to make the knowledge trustworthy and adequate.

Habermas (1984) states in an explicit way that different character of knowledge (expressed in different forms of sentences) requires different validity claims or forms of grounding. "Starting from the analysis of sentence forms, we can go on to clarify the semantic conditions under which corresponding sentence is valid. …. [T]he meaning of grounding changes in specific ways with changes in sentence form." (ibid. p. 39). This can be illustrated by the difference between a description and a prescription. Concerning descriptions, the main validity claim is truth. A description is valued if it is true or not. A valid description is a true one. A prescription is not valued concerning truth claims. Instead, it is valued concerning appropriateness. This is the case since descriptions and prescriptions are of different epistemic types. The epistemic character of a description (as a sentence) is that it gives a correct account of something that exists. The epistemic type of a prescription (as a sentence) is that it gives a useful recommendation for creating something to become.

Habermas' theory is harmonious with the pragmatist stance of this inquiry. Expressing sentences (as knowledge representations) are seen as *communicative actions*. This is also the case concerning explicit validity claims of such sentences/communicative actions. Such validity claims can be seen as *meta-discursive actions*.

2.3 Structure

The inquiry on DSE is presented in the following according to this disposition: The problematic situation and the need for inquiry (the research question) have been presented in the initial section above (1). After the elaboration of research approach in this section (2), it follows in the next section (3) an epistemological analysis of design science literature. This analysis leads to a conceptualization of an *epistemic logic of the design science process* and a *preliminary list of epistemic types in design science*. The following section (4) presents and investigates an empirical design case (digital transfer in social welfare allowances). The author has first-hand experience from this case. The case illustrates different epistemic types of knowledge items related to the identified epistemic logic of the design science process. Based on the literature analysis and the empirical case analysis, a coherent conceptualization of DSE is presented in the following section (5). This fulfills the transformation into a settled and determinate situation of the inquiry. The paper ends with discussion and conclusions (6). In this concluding section, possible uses of this design science epistemology are discussed.

3 Assumed epistemic types in design science

3.1 Design science process and knowledge creation

Hevner et al. (2004) describe design science in a fairly simple way to consist of build-evaluate cycles. This condensed view has been expanded by several other scholars into different process models. Kuechler and Vaishnavi (2012) have expanded the build phase into three (iterative) stages: 1) problem awareness, 2) suggestion and 3) development. A similar model is found in Peffers et al. (2007). In their model, there is an explicit stage on "define objectives of a solution" after the problem formulation stage.

Several scholars have explored the role and constituents of evaluation in DS. Venable et al. (2016) have presented a framework for evaluation in design science. They distinguish between 1) why to evaluate, 2) what to evaluate, 3) when to evaluate (ex-ante or ex-post), and 4) how to evaluate (in artificial or naturalistic settings). The temporal dimension has been further elaborated by Sonnenberg and vom Brocke (2012). They identify four different evaluation points in the design science process: 1) before design which means an evaluation of the problematic situation, 2) after design, but before construction, 3) after construction but before use (e.g.,through the use of prototypes) and 4) after use in its practice context. There are several suggestions in the literature concerning criteria for evaluation. General criteria for evaluating the IT artifact (instantiation) are suggested by March and Smith (1995, p. 261), "efficiency and effectiveness of the artifact and its impact on the environment and its users" and Hevner et al. (2004, p. 85), "utility, quality, and efficacy of a design artifact". One important insight, accounted for above, was the conduct of evaluation in different stages of the DS process.

Sonnenberg and vom Brocke (2012) and Verschuren and Hartog (2005) differentiate and relate criteria to different stage-types of evaluation. Confer also Prat et al. (2015) and Baskerville et al. (2015). One important conclusion from reading the literature on design science evaluation is that there are criteria expressing values both concerning the artifact and the use-context. We can speak of artifact-centric criteria and user/usage-centric criteria. However, sometimes these distinctions are blurred.

3.2 Knowledge abstraction in design science

The main outcome from design science in IS is considered to be an artifact following Hevner et al. (2004): "The result of design-science research in IS is, by definition, a purposeful IT artifact created to address an important organizational problem" (ibid. p. 82). In their seminal paper, there is a reluctance to include theories and other abstractions as results from DS; a position that has been softened in later publications (e.g.,Gregor and Hevner 2013).

Many scholars have advocated for a DS process characterized by different levels of abstractness. The DS knowledge development is often characterized by alternating between two layers of abstractness, although the labels are differing, as "abstract knowledge" vs. "concrete knowledge" (Sjöström and Ågerfalk 2009); "abstract knowledge" vs. "situational knowledge" (Goldkuhl and Lind 2010; Barquet et al. 2017); "abstract domain" vs. "instance domain" (Lee et al. 2011); "generic artifacts" vs. "situated artifacts" (Winter 2014); "nomothetic knowledge" vs. "idiographic knowledge" (Baskerville et al. 2015). It is clear in some of these publications, indicated in others, that the DS process is characterized by a continual movement back-and-forth between an abstract knowledge layer and a concrete/situational layer. This implies also the generation of intermediary knowledge as well as final DS knowledge contributions. Knowledge elements within DS can be 1) utilized (as *exterior input*), 2) generated and used as *intermediaries* within the DS process, and 3) generated as *final outcomes* from the DS endeavor.

3.3 Design theory and epistemic types

Design theory is considered, by several scholars, to be a main outcome from a design science endeavor. There are several contributions concerning constituents and structure of design theory. A pioneer contribution was made by Walls et al. (1992). A design theory is seen as a prescriptive theory integrating explanatory, predictive and normative knowledge (ibid.). The explanatory part of the theory is made up of so-called kernel theories, i.e.,background theories that could inform the prescriptive parts of the theory.

This means that other theories may be imported and integrated into the proposed design theory. A design theory comprises prescriptive knowledge for both design process and design product. The prescriptive essence of the design theory for the design product consists of meta-requirements, as "a class of goals", and "meta-design", as "a class of artifacts meeting the meta-requirements" (ibid. p. 42).

The relationships between explanatory knowledge and prescriptive knowledge in design theories were more thoroughly described by Goldkuhl (2004). An explanatory statement (of cause-to-effect type) can be transformed into a prescriptive statement (of means-to-end type) if the effect is considered to be desirable, i.e.,a goal. Goldkuhl (2004) emphasizes a multi-grounding approach to design theory; besides 1) an empirical grounding there should be 2) an internal grounding and 3) a theoretical grounding consisting of explanatory, normative (value) and conceptual grounding. The relationships and integration of conceptual, explanatory, normative and prescriptive knowledge in design theories are thus made explicit by Goldkuhl (2004). Kuechler and Vaishnavi (2012) build on Walls et al. (1992) and Goldkuhl (2004) when developing their framework for theory development in IS design science. They claim the importance of translating and adapting explanatory kernel theories to the specific circumstances of IS design (design relevant explanatory/predictive theory). Besides formal kernel theories, they also want to include tacit knowledge (experiences and insights) as a basis for the generation of design theory.

The importance to include explanatory background knowledge (kernel theories) is also emphasized by Gregor and Jones (2007). In their work on the anatomy of an IS design theory they include "justificatory knowledge" (equivalent to kernel theory) as a basis for proposed prescriptions. Gregor and Jones (2007) have transformed and expanded the Walls et al. (1992) design theory approach. Instead of "meta-requirements", Gregor and Jones speak of "purpose and scope of the system" and instead of "meta-design", they speak of "principle of form and function as an abstract 'blueprint' or architecture that describes an IS artifact" (ibid. p. 322). They have also provided additional elements to a design theory. The key constructs (entities of interest) have been made explicit. Anticipated state changes of an artifact (artifact mutability) have also been added.

Winter (2014) has also made a contribution to design theorizing, where he emphasizes the distinction between descriptive (explanatory) and prescriptive knowledge. Although it is easy to agree with this difference analytically, it seems that this author over-emphasizes such a difference. "It should be carefully differentiated whether 'theory-type' statements relate cause and effect (explanatory and/or predictive theory) or relate means and end (design theory). This line separates two 'worlds', the world of descriptive artifacts and the world of prescriptive artifacts." (ibid. p. 5). As stated above, the difference between cause-to-effect and means-to-end lies in whether the effect is considered as a desired state (an end).

In a review of different design theory anatomies, like Walls et al. (1992) and Gregor and Jones (2007), Baskerville and Pries-Heje (2010) claim that these approaches are "overly complicated" (ibid. p. 271). As a reaction to this, they propose that design theories should be divided into two distinct classes; 1) design practice theory and 2) design theory of design objects. The latter should be reduced to just consist of explanatory statements. These are described to be functional explanations stating relations between object features and requirements. However, their conceptualization of requirements seems to differ from Walls et al. (1992). They speak of "capability or conditions … possessed by a system" (Baskerville and Pries-Heje 2010, p. 274). It seems to be a focus on the means, and the ends (goals) are somewhat implied; "… needed by a user to solve a problem or achieve an objective" (ibid.). This type of explanatory clause of Baskerville and Pries-Heje (2010) has been further investigated by Niehaves and Ortbach (2016), where they emphasize the potential existence of multi-causality relationships between independent and dependent variables.

A similar design theory approach can be found in Venable (2006) who speaks of utility functions between 1) technological solutions and 2) business needs for problem resolution. Instead of explanations or prescriptions, he characterizes this theoretical knowledge to be predictive. Baskerville and Pries-Heje (2010) emphasize their similar theoretical clause to be explanatory but acknowledge its nature of being constructive and prescriptive as well. This is fully in line with the accounts in Goldkuhl (2004) and Kuechler and Vaishnavi (2012).

Not all design abstractions are made in the form of a complete design theory. Gregor and Hevner (2013) talk about *nascent design theories* that can consist of "constructs, methods, models, design principles, technological rules" (ibid. p. 342). The Action Design Research approach of Sein et al. (2011) explicitly uses the notion of *design principle* as an outcome of applying their approach. They do not present a clear definition of a design principle (although claiming it to represent design knowledge), but when studying their empirical case a clear pattern arises. A design principle is seen as some specific feature of an artifact and it can be related to desired (and sometimes unanticipated and undesired) consequences among users. They speak of the need for "an assessment of the artifact and design principles that it represents" (ibid. p. 42). There are other prescriptive knowledge contributions expressed in the DS literature. Dwiwedi et al. (2014) have made a literature review and have identified different types of DS knowledge contributions. Many of these seem to be of prescriptive nature (guideline, design principle, design pattern, design requirement, design recommendation, generative mechanism), however not yet matured to an explicit design theory level.

What epistemic types are assumed in the above reviewed design theory approaches? Most approaches claim the role of design theory to be *prescriptive*. There are however differences between how elements of prescriptive statements are conceptualized and labeled. *Explanatory knowledge* is also included in these design theory types; 1) sometimes as externally provided background theories (kernel theories), 2) sometimes as transformed and adapted background knowledge and 3) sometimes as explanatory equivalents of stated prescriptions or *predictions*. *Value knowledge* is explicitly included in some design theory approaches, but given different labels (meta-requirement, goal, purpose). In other approaches, it is rather kept implicit. The importance to stress *key concepts* in design theory is made by Goldkuhl (2004), "conceptual grounding", Gregor and Jones (2007), "constructs as entities of interest" and Winter (2014), "foundational constructs". Confer also the DS knowledge type "definitional knowledge" by Johannesson and Perjons (2014). This type of knowledge will be called *categorial knowledge* in the following.

3.4 An epistemic logic of the design science process

Design theory is seen as a fundamental outcome of DS research. Different epistemic functions of design theory have been indicated above. But, how about other types of knowledge in the DS process? Evaluation is not only used, as described above, for a final and summative evaluation of an IT artifact in use with the purpose of validating design theory. There are formative uses of evaluation during the DS process in order to improve knowledge concerning design. Evaluation plays generative roles in the design process when contributing with knowledge to direct the design in fruitful paths. As can be derived from DS process descriptions (e.g.,Peffers et al. 2007; Kuechler and Vaishnavi 2012) there are several knowledge contributions made in the design process. For example, there is knowledge about problematic situations, about objectives and values, and also about proposals for design. There may be evaluations made with reference to these different situations and objects.

Design science has been characterized as concerned with knowledge about a world-to-be as contrasted with a world-as-is. This is only partially true. Design science starts with a world-as-is (comprising its deficiencies and unexplored opportunities) and tries to transform it into a desirable world-to-be. Knowledge about the world-as-is is fundamental for the DS process. Such knowledge is however not a strictly neutral description of prevailing circumstances. The knowledge about current practices is based on implicit or explicit assessments. Several DS scholars state that problem formulation is the starting point of DS (Hevner et al. 2004; Peffers et al. 2007; Sein et al. 2011). Knowledge about problems and current practices forms a fundamental *background knowledge* for the design process in DS. This kind of knowledge is descriptive, but a more appropriate epistemic characterization is to state that it is *evaluative knowledge*. Problems aren't just there. They depend on human assessments of current affairs. This is an initial stage in all kinds of inquiries, triggered by experiences of difficulties and disturbances, and trying to find out "what works" and "what does not work" (Dewey 1910; 1938). More or less explicit in this evaluation and problem investigation are the values and goals of the practices. Problems and difficulties exist as deviations from what is desired.

Besides such a situational knowledge, there may also be an influence from extant abstract knowledge with relevance for the design topic; i.e.,what is called kernel theory by several scholars; cf. discussion above. Kernel theory is not generated within the DS process, but it is selected and furnished to the knowledge process and it is, therefore, pertinent to include it in an epistemological analysis.

Design science is about a possible world; a world that might come into existence. Fundamentally in IS design science is ideas about 1) better IT artifacts and 2) that these artifacts will improve human practices. The *ideational* character of DS needs to be accounted for. Artifact ideas are suggestions and proposals, which are continually developed and shaped during the design process. This ideational knowledge can be epistemologically characterized as *prospective knowledge*; i.e.,knowledge about the *possible*. The world-to-be is, however, not only a possible world. It is also a *desirable world*, which accounts for *normative knowledge* of goals and values.

Design science is not only about creating ideas about a future situation. It tries through building and intervention to create such future states; i.e.,designed artifacts and improved practices. After arriving at these new states, the corresponding knowledge about these changes needs to be articulated. Sometimes it is said that it is sufficient with a designed artifact as the result from DS research; a so-called proof-of-concept (Nunamaker et al. 2015). The artifact encapsulates knowledge about itself. However, from a scientific perspective, this knowledge needs to be extracted and justified in separate scholarly descriptions. Descriptions of artifacts and their use-effects should be articulated in the form of design principles or design theories. Such accounts can be said to function as *prescriptive knowledge* (Goldkuhl 2004; van Aken 2004); i.e.,how should we act in design (what artifact properties to strive for) in order to reach certain goals (improved states in use-practices).

An *epistemic logic of the design science process* can be formulated as a result of this analysis. Three stages can be identified with their respective knowledge types. This is summarized in table 1.

Design science process stage	*Kind of knowledge*	*Epistemic type*	*Corresponding world state*
Pre-design	1) Situational knowledge about problems and practice context 2) Abstract extant knowledge selected for potential use (kernel theory)	1) Evaluative background knowledge 2) Explanatory background knowledge	World-as-is
In-design	Ideas and proposals; values and goals	Prospective and normative knowledge	World-as-might-be
Post-design (=use)	Knowledge about artifact properties with related impact on use-situations	Prescriptive knowledge	World-as-become and world-to-become

Table 1. Types of knowledge and related world-states in the design science process

This epistemic logic of the design science process will be illustrated in the empirical case description below (section 4) and further elaborated in the clarified design science epistemology (section 5).

3.5 A preliminary list of epistemic types

This epistemological analysis of the design science literature has identified several different epistemic types. Table 1 describes three phases of the design science process and their associated main knowledge types. There are, however, more knowledge types identified through the epistemological analysis above. The following epistemic types have been identified and these will be furthered as candidates for the DS epistemological classification to come (section 5 below): Explanatory knowledge, predictive knowledge, normative knowledge, prescriptive knowledge, categorial knowledge, evaluative knowledge, and prospective knowledge.

4 An empirical design case: Digital transfer in social welfare allowances

In order to clarify different epistemological issues in IS design science, parts of an empirical DS case will be used. There will be no comprehensive description of this case. More detailed accounts of results have been presented elsewhere (Goldkuhl 2012a; Eriksson and Goldkuhl 2013; Goldkuhl 2016). The case description is not used to present a comprehensive process description or resulting design theory. The aim of this case description is to use it in an appropriate way for this inquiry on DS epistemology. The purpose of this case presentation is to empirically illustrate and analyze knowledge items of a design science process in order to state different epistemic types. The design case is concerned with digital transfer in social welfare allowances. The author has participated in a longitudinal e-government development concerning social welfare allowances. This project can be characterized as combined action research and design research.

4.1 Evaluation of current situation

A short presentation of the workpractice and its digital development follows: The responsibility for social welfare allowances resides within welfare boards of municipalities. People with severe problems to make a living can apply for social welfare allowances. It is necessary for municipal welfare officers to check the total economic situation (including other allowances) for an applicant. A social welfare officer needs to contact different national agencies and inquire if other allowances are given to the client. In the design project, we developed a multi-query application that digitally sends queries to several national agencies (e.g.,the Social Insurance Agency and the Board for Study Support). Immediate answers are obtained digitally and they are exposed to the social welfare officers in the multi-query application. This communication was earlier mainly conducted through telephone calls and for a minority of authorities through a slow batch query application.

The development of new IT artifacts started from problematic situations in the case handling of social welfare allowances. It was confirmed that sometimes erroneous decisions were made by the social welfare boards concerning social welfare allowances. It could be in either way; the clients could get too much money or too little. The clients should in their applications for social welfare allowances state all relevant economic information (that contained already given allowances of other kinds). The important task of the social welfare officers was to check the validity of this information. She (in most cases it was a female) needed to contact several national agencies to check the figures. This was a cumbersome work. There were many different types of allowances to keep in mind and to check for the social welfare officer. It took a lot of time to collect and check all relevant information since this was made mainly through telephone calls. It was experienced as difficult to collect this information, which had the consequence that some relevant information might be missed. The consequence could be a lack of information as a decision basis. The oral transfer of information over the telephone was not considered safe. Sometimes misunderstandings could occur concerning allowances, periods and amounts. The consequence could be erroneous information as a decision basis. This could be the case if the applicants had submitted (unwittingly or intentionally) erroneous information and the social welfare officer had not checked its validity.

The social welfare officers complained that it took so much time to collect and check the information for the applicants. This paperwork hindered them to interact with the clients and give them support in their vulnerable situations. The social welfare officers wanted to have more time to work directly with the clients in helpful ways.

The insecure and cumbersome situation with information collection and transfer did not only result in information shortage and information error. It could also, in some instances, lead to information surplus. It was hard for the case handlers at the national agencies, in stressful telephone calls, to check the authorization of the municipal officers to retrieve personal information about clients. There was an obvious risk that too much information was delivered in relation to privacy regulations. This problem analysis has been summarized in table 2 expressing cause-effect relationships. What is characterized as a cause can be reasons for action, i.e.,a kind of teleological explanation.

This problem analysis was based on certain apprehended values in the different workpractices. An articulation of goals as a basis for the design was made. They can be summarized as follows:

- Efficient social welfare case handling
- Correct decisions on social welfare allowances
- (Time for) adequate support to social welfare clients
- Privacy in social welfare case handling (avoidance of information surplus)

It had been legislative obstacles for an efficient digital transfer of information in the social welfare sector due to restrictive privacy concerns. A new statute had however been issued that gave better possibilities for a direct digital transfer of specified information about clients from national agencies to municipalities. This opened a window for a new digital design that was exploited in this research project.

Cause	*Effect*
Erroneous information about clients and/or lack of information about clients.	Erroneous social welfare allowance decisions.
No information submitted by clients and no collection of client information is made from national agencies.	Lack of information about clients (information shortage).
Cumbersome and time-consuming to collect client information and/or many other allowances to keep in mind and check.	No collection of client information is made from national agencies.
Misunderstandings in telephone communication between the municipality and national agency and/or client have submitted erroneous information (on purpose or by mistake).	Erroneous information about clients.
Cumbersome and time-consuming to collect client information.	Lack of time for social welfare officers to work with direct support to clients.
Hard to check authorization during stressful telephone calls.	Information given to officers without authorization (information surplus).

Table 2. Problem statements as cause-effect relationships

This legislative change was a new strength in the workpractice. The analysis of what-is was not only based on a problem investigation. A kind of appreciative inquiry was also performed. The following strengths of the governmental practices were identified:

- New legislation that permits an immediate digital transfer of client information from national agencies to municipalities
- There existed digital resources (registers) at the national agencies that contained relevant information about clients for case handling of social welfare allowances
- Committed social welfare officers with ambitions to give proper support to social welfare clients

It was important in the DS study to obtain a deep understanding of the current practice as a basis for the design of new IT artifacts. As can be seen above, this evaluation of current practice included investigations of problems, goals, and strengths.

4.2 Design of new IT artifacts

A new digital solution was developed consisting of several interoperating IT artifacts. As said above, a multi-query application was developed for the social welfare departments in municipalities. This IT artifact is used by social welfare officers to send queries to all relevant national agencies for the collection of economic information about applicants. The resulting answers are presented in a well-structured way in a user-interface, which is easy to navigate between overview and many details. This digital solution was developed according to the new legislation. The digital transfer of information was restricted to those items explicitly mentioned in the new statute. However, the Data Inspection Board complained that the digital solution was not secure enough. It is stated in the regulations that there must be an open welfare case and that there should be technical obstacles to state queries concerning other persons. A new solution was designed as a result of these complaints. The multi-query application was furnished with new functionality. After this change, the software application could check that there was an open welfare case by reading the database of the social welfare case system. Only after this check, it was possible to send a query to the national agencies.

In figure 1, there is a structured description of primary artifact functions and their relations to workpractice goals. The artifact functions have been divided into 1) external properties (i.e.,functions directly related to users) and 2) conditional properties (i.e.,internal or structural functions). External functions serve the users directly and conditional functions influence the external functions of the artifact.

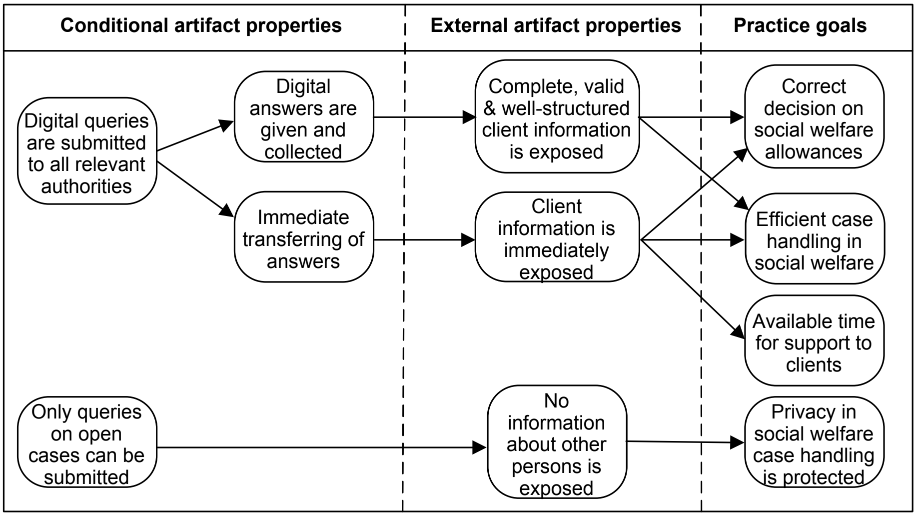

Figure 1. Structured description of conditional and external properties of the IT artifacts, and workpractice goals

5 Towards a clarified design science epistemology

5.1 Epistemic types in design science studies

The literature analysis produced a list of preliminary epistemic types (section 3.5): explanatory knowledge, predictive knowledge, normative knowledge, prescriptive knowledge, categorial knowledge, evaluative knowledge, and prospective knowledge. The analysis of the empirical case in section 4 has added three epistemic types to this list. Evaluative knowledge was developed in the DS case. There were studies of problems and strengths in the studied practice (see section 4.1). This means that evaluative knowledge can be of two kinds; negative evaluations (problems) and positive evaluations (strengths). Evaluative knowledge that describes problems will be labeled *critical knowledge*. Evaluative knowledge that describes strengths will be labeled *appreciative knowledge*. The empirical analysis featured also properties of IT artifacts to be an important knowledge type. Different conditional and external properties of the IT artifact were described (figure 1). The designed IT artifact is a central object in the DS study (categorial knowledge), and this designed object appears with certain properties. The knowledge of such (designed) properties will be called *attributive knowledge*. These three types (critical knowledge, appreciative knowledge, attributive knowledge) are added to the list of epistemic types from section 3.5. It seems that the investigated literature (section 3) was not sufficiently specific about such knowledge types. A juxtaposition of these different epistemic types is made in table 3.

Table 3 lists the epistemic types (first column) and clarifies them through a principal clause (second column) and illustrates them through examples from the social welfare case (third column). This empirical illustration implies also that all epistemic types can be said to exist in the empirical case.

Some more comments need to be done to the list in table 3. One epistemic type (from the preliminary list in section 3.5) has been excluded: predictive knowledge. Predictions and explanations are considered of a similar epistemic kind. There is a common clause-type of cause-to-effect for both these statements. I follow here the analysis of theory construction made by Reynolds (1971). He equates explanation and prediction in principle and states that the difference lies in temporality: "*Predicting* events that will occur in the *future* and *explaining* events that have occurred in the *past* are, except for a difference in temporal perspective, *essentially the same activity* as long as scientific statements are abstract" (ibid. p. 3; my emphasis). To this one can add, that an explanation seems usually to be directed from a phenomenon (considered as an effect) to stating its efficacious cause, and that a prediction seems usually to be directed from a phenomenon (considered as a cause) to stating its potential effect. There exist, however, scholars in IS that differentiate between explanatory and predictive theories. Gregor (2006) sees predictions as weaker than a strict causality. Predictions are statements that contain "correlations between two variables [that] does not necessarily imply a causal relationship" (ibid. p. 626). It is, however, stated by the same author that "this type of theory in IS do not come readily to hand, suggesting that they are not common" (ibid. p. 626). My conclusion is, following Reynolds (1971), that we do not need predictive knowledge as a separate epistemic type in a design science epistemology. Predictive knowledge is mainly covered by explanatory knowledge. It can also be covered by the special cases of causal statements that are prospective knowledge (proposed and hypothetical means-to-end knowledge) and prescriptive knowledge (validated means-to-end knowledge). The relationships between explanatory, prospective and prescriptive knowledge will be explained in more detail in section 5.2.

A further comment on explanatory knowledge and causality is needed. In table 3, explanatory knowledge is defined through causality in the following way "stating that something (=cause) influences/produces something (=effect)". In an IS context, this should not be interpreted always in a strict deterministic way. Depending on the characters of phenomena, the relationship between the cause and its effect will vary. In the social realm, there exist intentional and value-seeking human action and social interaction based on affordances in instruments and interpretations of meaning (Blum-

Type of Knowledge	*Principal clause*	*Example (from social welfare case)*
Evaluative knowledge	Stating that something is assessed to be in some way	See examples of problems and strengths
Critical knowledge	Stating that something is considered to be negative (=problem)	Cumbersome and time-consuming to collect client information about clients
Appreciative knowledge	Stating that something is considered to be positive (=strength)	Committed social welfare officers with ambitions to give proper support to social welfare clients
Normative knowledge	Stating that something is desirable (=goal)	Correct decisions on social welfare allowances
Explanatory knowledge	Stating that something (=cause) influences/produces something (=effect)	Lack of information about clients can give erroneous social welfare allowances decisions
Prospective knowledge	Stating that something is possible	Social welfare artifact with immediate exposure of client information may contribute to correct decisions on welfare allowances
Prescriptive knowledge	Stating how to (=means) reach something desirable (=end)	Social welfare artifact with immediate exposure of client information contributes to correct decisions on welfare allowances
Categorial knowledge	Stating that something exists	Information about clients
Attributive knowledge	Stating properties of something	Shortage of client information

Table 3. Different epistemic types in design science explained through principal clauses and illustrative examples

er 1969; Gibson 1979; Habermas 1984; Winch 1990). This constitutes an efficacy between conditions and effects with a softer socio-pragmatic causality. There might be cases with a strict necessity between cause and effect as e.g.,the execution of software code in a computing machine. There will be other cases involving human interpretation/action and social interaction where causes/conditions will influence/facilitate the production of effects without any strict necessity. Such different forms of causality are accounted for in IS research (Markus and Robey 1988; Hovorka et al. 2008; Gregor and Hovorka 2011).

5.2 A conceptual map: Relationships between epistemic types

The design science epistemology is visualized through a conceptual map (figure 2) of different knowledge types that are relevant in design science. The conceptual map depicts knowledge types (boxes) and semantic relationships (arrows) between them. Arrows do not describe sequences or processes. An arrow indicates a reading direction of the semantic relation as common in conceptual models. The basic structure of this model follows the epistemic logic of the three stages with their corresponding primary epistemic types (pre-design evaluative and explanatory knowledge; in-design prospective knowledge; post-design prescriptive knowledge); cf. table 1. These primary knowledge types are dependent on and built up from other more basic epistemic types. In-design knowledge is key characterized as *design hypothesis* and post-design knowledge as *design principle*. These concepts will be further elaborated below.

Explanatory knowledge plays important roles in all three stages. The roles are however differing which will be shown below. Explanatory knowledge is built from the two parts in the clause; the cause-part and the effect-part. Certain categorized phenomena are related causally through these explanatory clauses. Each part can be said to comprise a description of some phenomenon. Phenomena can be 1) *objects* or *processes* and 2) different *properties* of them. This can be seen to be a kind of realist ontology (Evermann and Wand 2005), however, expanded beyond plain physical objects to include social/institutional objects (Searle 1995; March and Allen 2014). There can be institutional objects talked about such as applications and decisions (following the social welfare case from above). Explanatory knowledge is built up from descriptive knowledge about the world (figure 2). Such descriptive knowledge is here, following the realist ontology mentioned, differentiated into 1) knowledge that identifies and categorizes objects or processes (*categorial* knowledge) and 2) knowledge of *attributive* kind, i.e.,characterizing objects/processes by stating properties of them. This fundamental division into objects, processes, and properties is directly reflected in language through the use of

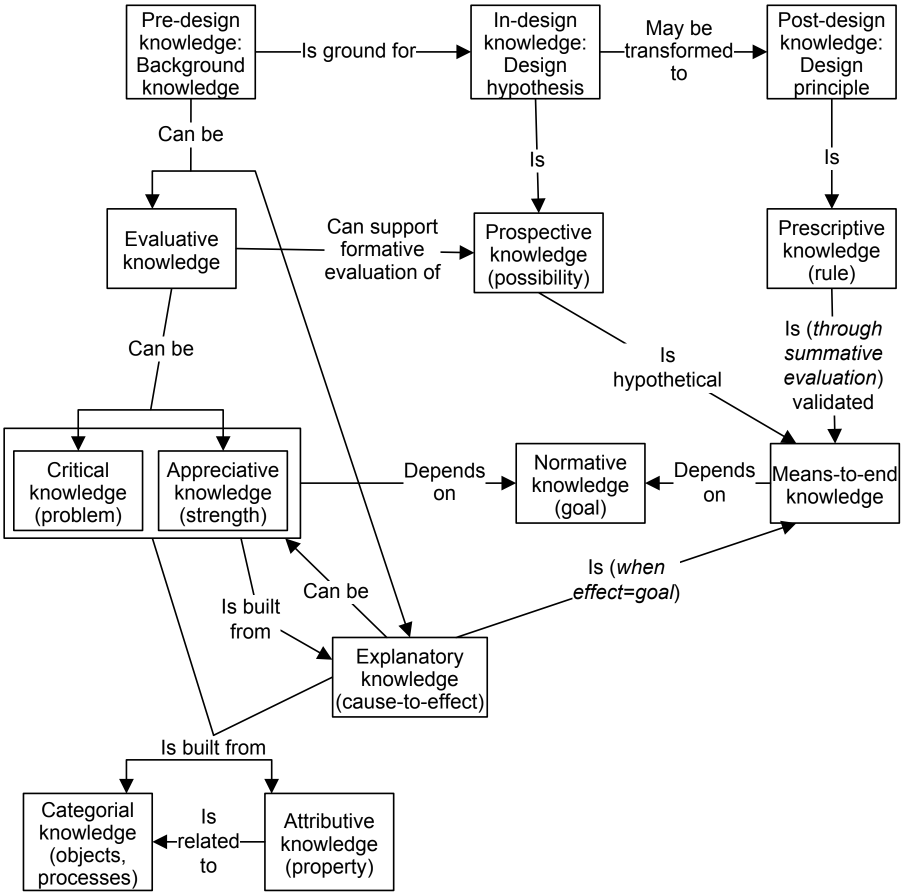

Figure 2. Conceptual map: Epistemic types of design science knowledge

nouns, verbs, and adjectives (Wittgenstein 1958). It is far beyond the scope of this paper to dig further into an appropriate socio-technical ontology for IS design science; cf. Goldkuhl, (2002; 2019) for more elaborate distinctions. Only some elementary constituents of a socio-technical world are described here as fundamental building blocks for explanatory statements (see above and below).

In the pre-design stage, the focus is on the current practice situation. Evaluations are made partially based on *explanatory cause-to-effect descriptions* of the current situation. As described in the empirical case, there can be evaluative statements about problems (i.e.,critical knowledge) and about strengths (i.e.,appreciative knowledge). Such knowledge will usually depend on normative knowledge (values/goals) as a means to articulate why something is considered negative or positive. Normative knowledge is necessary in order to detect any deviation between current situation and desired situation. As part of the pre-design background knowledge, there can also be explanatory knowledge of abstract character as selected kernel theories from the scholarly knowledge base.

Explanatory knowledge is also used in the in-design and post-design stages but in another shape. Here, the cause-to-effect clause is transformed into a *means-to-end clause* (Goldkuhl 2004). Means-to-end clauses are prescriptive because the end is desired. However, in design science it should be important to differentiate between 1) *hypothetical means-to-end clauses* occurring during design as a kind of *prospective* knowledge, describing hypothetical and desirable possibilities however not yet finalized (in-design knowledge) and 2) *validated means-to-end clauses* that are justified through observations of use-situations (post-design knowledge). The latter will give rise to proper *prescriptions*, i.e.,advising certain means to instantiate in order to reach certain desired states (i.e.,ends). A means-to-end clause as in-design knowledge is characterized as a *design hypothesis* since it describes an anticipated artifact property and its relationships to use situations. A means-to-end clause as post-design knowledge is characterized as a *design principle* since it expresses prescriptive knowledge of an artifact property that may contribute to a desired use situation.

Prospective knowledge (belonging to in-design knowledge) is thus considered to be hypothetical means-to-end knowledge. This may comprise ideas about artifact properties (i.e.,means) and how such properties may contribute to a desired practice situation (i.e.,end). Prescriptive knowledge (belonging to post-design knowledge) is thus considered to be validated means-to-end knowledge. It is, however, important to add that there will probably be a gradual shift from the prospective in-design knowledge to the prescriptive post-design knowledge. Different projected design ideas may be visualized in models and later instantiated in prototypes more or less advanced. During an iterative use of models and prototypes, design ideas are gradually shaped and also given more credibility. Ideas and possibilities are becoming real through building, testing and evaluating. Formative evaluation efforts during the design phase may contribute with evaluative knowledge to a continual refinement of the design.

In order for post-design knowledge to reach the level of prescriptive design theories (Walls et al. 1992; Gregor and Jones 2007) there needs to be empirical evaluations of artifact use situations. Results from such post-evaluations can be abstractions of empirical data in the form of explanatory cause-to-effect clauses. These explanations can be transformed into prescriptive means-to-end clauses (Goldkuhl 2004; Kuechler and Vaishnavi 2012). This means that prescriptive means-to-end knowledge will build on evaluative knowledge of testing and using an artifact. Prescriptive post-design knowledge is seen as a transformation of such post-evaluative knowledge. It will be a result of a summative evaluation of artifact use.

As can be seen from above, evaluation will occur at different stages of a design science process, which also has been noted by several scholars (e.g.,Sonnenberg and vom Brocke 2012; Baskerville et al. 2015). Evaluation can be performed following different strategies (how), on different evaluation objects (what) and aiming for different kinds of knowledge (why). A summary related to DSE can be found in table 4.

Knowledge stage	*HOW: Evaluation type (strategy)*	*WHAT: Evaluation object*	*WHY: Evaluation purpose (epistemological orientation)*
Pre-design	Empirical pre-evaluation	Current practice	Establish a diagnosis background for design (explanations, values)
In-design	Formative evaluation during design	Emergent design ideas described in models and prototypes	Improvement of design ideas/ hypotheses (prospective knowledge)
Post-design	Summative empirical evaluation	Use of designed artifact in practice	Validation of design principles (prescriptions)

Table 4. Different kinds of evaluation in design science studies

5.3 Design principles as outcomes from design science studies

Before post-design knowledge can be claimed to have reached the level of a proper design theory such knowledge can be expressed as design principles (Gregor and Hevner 2013) possibly in a nascent design theory. A design principle, according to Sein et al. (2011) and discussed in section 3.3 above, expresses some property of an artifact and it can be related to desired states in the practice context. This follows a means-to-end pattern. The structured relationships between different artifact properties and practice goals, as described in figure 1 of the design case above, seem to equate such a design principle of Sein et al. (2011). When using a proposed terminology of artifact properties and practice goals, there is no need to use any terminology of meta-requirements and meta-designs as in Walls et al. (1992). This proposed approach also sharpens what is a *feature* of the artifact and what is an *effect* of using such an artifact-feature.

The basic means-to-end clause in IS design science (following the examples from the empirical case) has the following basic structure:

- Means: functional and external property of the IT artifact
- End: desired workpractice situation (i.e.,some desired fundamental value)

There can also be sub-means such as conditional artifact properties (cf. figure 1). The external artifact properties are dependent on such conditional properties. It is important to acknowledge that the *means are,* not only artifacts as such, but *specific properties of artifacts*. Such knowledge is attributive knowledge, i.e.,an expression of some specific property of an object (in this case an IT artifact). This can be exemplified with 'client information is immediately exposed' as a functional property of the focused IT artifact. Ends (goals) are situations in practices where some desirable feature is emphasized in such a situation (e.g.,correct, efficient, available, protected). A feature is of course not just a feature; it is a property of something. This can be exemplified by 'Correct decisions on social welfare allowances', where 'correct' is an attribute of the object 'decision on social welfare allowances'.

As stated above, a design principle from a DS study may typically consist of such a means-to-end clause; i.e.,a property of an IT artifact may contribute to a desired practice situation. Figure 3 illustrates the structure of design principles including both conditional and external artifact properties. The figure also illustrates that such sub-

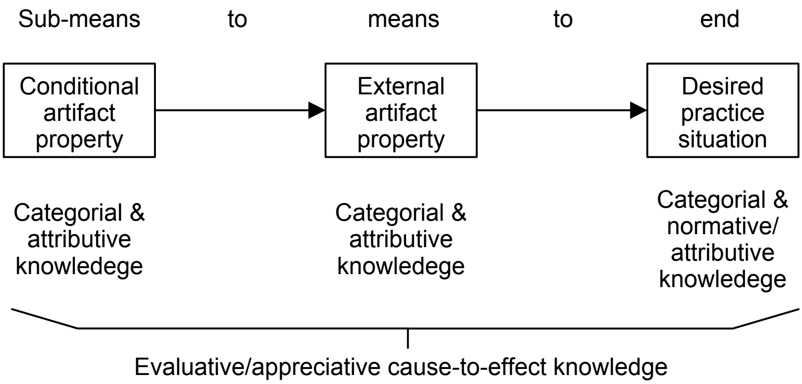

Figure 3. Structure and dependencies of a design principle as an outcome from a design science study

means/means are constituted by categorial and attributive knowledge: IT artifact (as category) with certain properties (as attributes). The end, as a desired practice situation, is constituted by such categorial and attributive knowledge with the important addition that the attribute is considered as something valuable; i.e.,a kind of normative knowledge. The design principle should not be a mere design hypothesis (as prospective knowledge), but it should be the result of some empirical and evaluative study. In figure 3, this is illustrated, by stating that a design principle is dependent on evaluative cause-to-effect knowledge. This type of evaluative knowledge should be seen as appreciative since it emphasizes positive aspects of practices and IT artifacts.

It should be noted that conceptualizing knowledge in means-to-end chains is usually a matter of relative characterization. Something that is considered a means, can also be considered as an end in relation to its sub-means. To exemplify, a functional property of an IT artifact that is instrumental (i.e.,a means) in relation to desired practice situation, can also be considered as an objective for design, i.e.,in this case an intermediate goal that is dependent on different sub-means. This implies that an artifact property can be considered a means or an end depending on its role in means-to-end clauses.

5.4 Knowledge grounding

The conceptual map in figure 2 uses different epistemic types and clarifies the relationships between them. As can be seen from the clauses and examples in table 3, these different knowledge types have different sentence forms. This means also that these knowledge types need different grounding principles following Habermas (1984) as stated above (section 2.2) when introducing the notion of epistemic type. The principle ways of grounding these different epistemic types are shown in table 5. Some examples of these groundings are explicated here. The two types of evaluative knowledge (problems, strengths) need to be descriptively correct; i.e.,they should be considered veracious. The specific evaluative type (problem vs. strength) needs to be justified argumentatively. Something that is claimed to be a problem needs to be motivated as something that is deemed negative in the practice. Something that is claimed to be a strength needs to be motivated as something that is deemed positive in the practice. In table 5, there are also references to literature for these different epistemic types; i.e.,this table functions also as a kind of theoretical grounding of the different epistemic types.

Type of Knowledge	*Way of grounding*	*Theoretical basis*
Evaluative knowledge	Descriptive correspondence and assessment motivation	Dewey (1938); House and Howe (1999)
Critical knowledge	Descriptive correspondence and problem motivation	Dewey (1938); Rittel and Webber (1973)
Appreciative knowledge	Descriptive correspondence and strength motivation	Ludema et al. (2001)
Normative knowledge	Motivated volition	House and Howe (1999); Rescher (2000)
Explanatory knowledge	Descriptive correspondence and adequate abstraction	Reynolds (1971); Goldkuhl (2004); Gregor (2006)
Prospective knowledge	Innovativeness and valuable to explore	Dewey (1938); Lubart (2000)
Prescriptive knowledge	Appropriateness in action	Rescher (2000); Goldkuhl (2004); Gregor (2006)
Categorial knowledge	Existence and proper abstraction	Searle (1969); Strauss and Corbin (1998); Evermann and Wand (2005); Gregor (2006)
Attributive knowledge	Existence and proper characterization	Searle (1969); Strauss and Corbin (1998); Evermann and Wand (2005)

Table 5. Different epistemic types in design science described through ways of grounding and theoretical basis (literature references)

As described above, in design science there are differentiations made 1) between situational problems and abstract classes of problems and 2) between specific designs and

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abstract classes of solutions (e.g.,Lee et al. 2011; Sein et al. 2011; Gregor and Hevner 2013). How is the presented design science epistemology related to this dichotomy? A proper design science study should alternate in a constructive and generative manner between a situational design focus and an abstract theorizing orientation. This means that all epistemic types can be expressed in 1) a specific and situational manner aiming for a specific artifact design and in 2) a de-contextualized and abstract manner aiming for design principles and design theory.

6 Discussion and conclusions

6.1 Utilizing design science epistemology

How can this knowledge of DSE be used in research processes and publications from such research? The phasing of design science described in this paper is important to acknowledge; i.e.,the stages of pre-design, in-design and post-design. There are different primary epistemic types associated with these different stages; background evaluative and explanatory knowledge in pre-design, prospective means-to-end knowledge in in-design, and prescriptive means-to-end knowledge in post-design. The design science scholar needs to be well aware of these different epistemic types and address each of them in fitted ways. These different primary epistemic types rely also on *supportive knowledge* of other epistemic types, which can be seen in the conceptual map (figure 2) and also in textual descriptions above (especially section 5). The design science epistemology contributes useful knowledge of relationships between different epistemic types in such a research process. The epistemological classification can be used as a complement to existing process models in design science, such as Peffers et al. (2007) and Kuechler and Vaishnavi (2012)/Vaishnavi and Kuechler (2015). In table 6, these two process models have been mapped together with identified knowledge types associated with each process stage. Through a close reading of these publications, different knowledge types have been identified and related to each process stage in table 6. A fourth column, in this table, contains identified epistemic types from the presented DSE. This can be compared with the knowledge types in the two DS process models (columns two and three). The epistemological classification of DSE in this paper has a more comprehensive epistemic content than the two established process models.

In the two process models, there is an emphasis (in pre-design) on identification of problems. The DS epistemology adds evaluative strength knowledge to this. An appreciative inquiry is important in order to identify not yet exploited opportunities and

Knowledge stage	*Stages following Peffers et al. (knowledge types)*	*Stages following Kuechler and Vaishnavi (knowledge types)*	*Knowledge types DSE*
Pre-design	Problem identification and motivation (problems, value motivation)	Awareness of problem (problems)	Evaluative/explanatory situational knowledge (problems, strengths) Normative knowledge Explanatory abstract knowledge
In-design	Define the objectives for a solution (objectives) Design and development (functional specification)	Suggestion (kernel theory, design ideas) Development	Prospective knowledge (design hypotheses = means-to-end) Normative knowledge Evaluative formative knowledge
Post-design	Demonstration (knowledge for artifact use). Evaluation (knowledge of artifact use) Communication (relevant aspects of DS study)	Demonstration (knowledge for artifact use) Evaluation (knowledge of artifact use) Communication (relevant aspects of DS study)	Prescriptive knowledge (design principles = means-to-end) Evaluative/explanatory knowledge of artifact use Normative knowledge

Table 6. Knowledge types in design science process models

practice traits that should be sustained in a change process. Glimpses of normative knowledge in pre-design can be found in Peffers et al (2007): "Define the specific research problem and *justify the value* of a solution" (ibid. p. 52; my emphasis). To this, one must add the importance to articulate and apply normative knowledge for a proper evaluation of current situation. An empirical evaluation of current situation is in DSE also paralleled by theoretical inquiries into the knowledge base of background explanatory theories to reach an adequate theoretical grounding of design proposals. This is also emphasized by Kuechler and Vaishnavi (2012) but in their process model placed in direct relation to in-design (the suggestion stage).

Ideational knowledge in the in-design stage is emphasized by Vaishnavi and Kuechler (2015) in a separate suggestion sub-stage. Peffers et al. (2007) have clarification of objectives (i.e.,normative knowledge) in a preceding sub-stage before designing. In addition to these knowledge types, DSE emphasizes prospective knowledge as an explicit clarification of means-to-end, i.e.,functional relationships between artifact properties and desired practice situations. DSE acknowledges also formative evaluations of design hypotheses that may occur in different degrees of manifestation.

In the post-design stage, both referenced process models acknowledge the need for evaluation of artifact use. Kuechler and Vaishnavi (2012) are explicit about explanatory/prescriptive design theory as a primary outcome from DS. In DSE, the essential outcome from post-design is seen as design principle as a transformation and validation of design hypothesis from in-design.

Scholars that follow any of these two established DS process models can thus add some more epistemological reflection and articulation in different stages (table 5). The presented DS epistemology does not prescribe an exhaustive use of epistemic types in all DS studies. It contains a map with different epistemic types and relationships between them. There will always be an open issue in each DS endeavor how ambitious the epistemological development should be conducted.

The presented design science epistemology could also influence the way a DS study is reported in a scholarly publication. Gregor and Hevner (2013) have made a thorough proposal for how to structure a design science publication. They present a publication schema with seven sections (summarized below in table 7; first column) and they comment similarities with and differences to an ordinary empirical paper. In general, the presented DS epistemology fits well into their publication schema. However, some amendments are possible to make to their publication schema if one follows the structure, contents, and insights of DSE more faithfully. A slightly modified publication schema is suggested in table 7 (second column). The two publication schemas are descriptively compared in table 7 and also in the text below. Table 7 contains some key characteristics in parentheses for each schema and section. These characterizations are formulated in ways compliant to the terminologies of each approach. This means that in some cases the differences are more terminological than conceptual.

Pre-design, through evaluative knowledge of problems and strengths in current practices, is emphasized in DSE. Gregor and Hevner (2013) include such knowledge in the introductory section. In the DSE variant, this knowledge is considered as vital for

<table>
<tr><th>Gregor and Hevner publication schema</th><th>DSE publication schema</th></tr>
<tr><td rowspan="2">1. Introduction (problem definition and significance; purpose and scope of artifact; research objectives)</td><td>1. Introduction (general background and purpose of research)</td></tr>
<tr><td>2. Diagnostic base (pre-design evaluative knowledge with explicit normative reflection)</td></tr>
<tr><td>2. Literature review (extant descriptive and prescriptive knowledge)</td><td>3. Literature review (explanatory knowledge from knowledge base)</td></tr>
<tr><td>3. Method (applied research approach)</td><td>4. Method (emphasizing the epistemic logic)</td></tr>
<tr><td rowspan="2">4. Artifact description (description of artifact; possibly design search/development process)</td><td>5. Design process (emergence of design hypotheses; formative evaluation in in-design)</td></tr>
<tr><td>6. Artifact description (conditional and external properties of artifact)</td></tr>
<tr><td>5. Evaluation (criteria for and result from evaluation)</td><td>7. Post-evaluation (evaluative knowledge with relationships between artifact properties and practice situation; founded in normative knowledge)</td></tr>
<tr><td>6. Discussion (interpretation of results; in some cases, extraction of design principles; implications of results; summary)</td><td>8. Design principles (explication of prescriptive means-to-end knowledge)</td></tr>
<tr><td>7. Conclusions (important findings)</td><td>9. Concluding discussion (implications; summary)</td></tr>
</table>

Table 7. Design science publication schemas: a comparison

the DS process and it has therefore been given a separate section (2). There is a section 4 in Gregor and Hevner (2013) containing artifact description. They describe the content of this section to "include … perhaps, the design search (development) process that led to the discovery of the artifact design" (ibid. p. 350). In DSE, the in-design stage is considered as vital and hence also the reporting of this knowledge process. Therefore, the optional remark by Gregor and Hevner ("included ... perhaps") (2013) is considered as too weak. This in-design part of the DS process is given a separate section in the DSE schema: "Section 4 Design process". The focus should be on the emergence of design hypotheses based on alternations between building and formative evaluation. This can be equated with the view of explicating a theory through the description of the theorizing process of interim struggles with intermediate results (Weick 1995). Design principles (as means-to-end knowledge) are considered in DSE as a key outcome from a design science study. It is an outcome from the post-design stage and it builds upon knowledge from the two previous stages. In the DSE schema, this prescriptive knowledge has a more prominent place in a separate section (8 Design principles). In the Gregor and Hevner (2013) schema, presentation of design principles was included as one part in the Discussions section (6). Other parts (such as implications) in this Discussions section have (in DSE schema proposal) been moved to the last section (9 Concluding discussion). As Gregor and Hevner (2013, p. 350-351) state "there is often difficulty representing the design of a complex artifact in the space that is allowed in a journal". The Gregor and Hevner (2013) publication schema is ambitious, and the DSE schema can be considered as even more ambitious. This points to dividing the reporting into several papers. There exist several possible strategies for dividing a DS study into several papers. One possibility is slicing the artifact into different clusters of artifact properties. Each such property cluster can be described in a comprehensive way concerning pre-design, in-design and post-design following either of the two publication schemas (table 7). Another publication strategy is to divide the publications along with the DS staging. For example, a three-paper presentation could consist of: 1) one paper with a focus on *pre-design knowledge* (background evaluations) including sketchy design proposals (prospective in-design knowledge) as potential responses to identified problems; and 2) one paper with in-depth descriptions of artifact properties (*in-design knowledge*) with hypothetical use-effects as desired ends (design hypotheses) including references to background knowledge motivating the suggested designs; and 3) one paper with focus on prescriptive *post-design knowledge* (design principles), where validations of proposed design properties are presented.

The suggestions above are concerned with concrete aspects of DS research (management of DS process and publications). The DS epistemology can also be used to stimulate further philosophical reflection on DS in IS. This paper has taken a pragmatist stance in its inquiry and how to conceptualize different epistemic types. There are other possible angles for philosophical reflections as stated by other scholars; e.g.,interpretivism (Niehaves 2007) and critical realism (Carlsson 2010).

6.2 Concluding remarks

This paper has, through an empirically informed epistemological inquiry, shown the diversity of design science epistemology. There is a *rich epistemological landscape* to address in design science and there is a great need for DS scholars to be well aware of different epistemic types and the respective ways of how to express and ground such differing knowledge. This paper has contributed a clarification of a design science epistemology with different epistemic types related to different stages of the design science process. Different epistemic types have been exemplified through an empirical case. Ways to express knowledge types have been proposed in principal clauses. Ways of grounding have been clarified for each epistemic type. This design science epistemology, provides DS scholars with instruments 1) to plan the DS knowledge progression process, 2) to characterize different knowledge items epistemologically (i.e.,to assign each to an epistemic type), 3) which helps scholars to the find suitable ways for grounding this knowledge and to report them properly.

In a simplified differentiation between behavioral science and design science, the former is associated with truth of what-is and the latter with utility and prescriptions for what-to-be. Such a differentiation overlooks the overlaps and similarities between behavioral science and design science. In order to create new artifacts and prescriptive knowledge for the design of artifacts, there is a need to acknowledge the artifacts and the corresponding new prescriptive knowledge as a response to problematic situations of what-is. Truthful knowledge about current situations (what-is) is indispensable in research through design. Evaluative and explanatory knowledge is a necessary starting point of design science studies. Evaluative and explanatory knowledge is also a necessary end point of design science endeavors since it is through such knowledge that design principles and prescriptions within a design theory are grounded.

This paper has also added to the discourse on what makes a design science study, with its focus on designing artifacts, to a scientific endeavor. Previously, arguments have been stated that it is the degree of innovation and novelty that is significant (Hevner et al. 2004) or the rigor in the development process (Iivari 2007). My main argument is that a design science study should produce artifacts and grounded knowledge connected to those artifacts. If no grounded knowledge is produced, it is hard to claim the study to be scientific. This makes us turn to epistemology and argumentative rationality (Habermas 1984; Goldkuhl 2004) as foundations for a design science process. A key characteristic in DSE is the inherent knowledge progression from evaluative background knowledge to design hypotheses and design principles.

What is next for this design science epistemology, i.e.,what about future research? The obvious and primary use and influence are to apply it as a guide for developing, validating and expressing different types of knowledge in DS studies and to report about experiences from such use. The hope that follows with this paper is to get DS scholars better prepared to navigate in the complex epistemological landscape of DS and to focus on those knowledge types that are important in their DS endeavors in order to produce impactful design science studies. This DS epistemology might also be used as an instrument for investigating design science studies/publications in retrospect in order to push existing DS knowledge further. Such different uses may inform further development of this design science epistemology. A more radical future research task would be to use the developed design science epistemology as a foundation for a more thorough re-conceptualization of design science and its different sub-activities such as problem articulation, design thinking, artifact creation, evaluation, data generation, and theorizing.

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