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The Anatomy of a Design Theory

Shirley Gregor
The Australian National University
Shirley.Gregor@anu.edu.au

David Jones
Central Queensland University
d.jones@cqu.edu.au

Abstract:

Design work and design knowledge in Information Systems (IS) is important for both research and practice. Yet there has been comparatively little critical attention paid to the problem of **specifying design theory** so that it can be communicated, justified, and developed cumulatively. In this essay we focus on the structural components or anatomy of design theories in IS as a special class of theory. In doing so, we aim to extend the work of Walls, Widemeyer and El Sawy (1992) on the specification of information systems design theories (ISDT), drawing on other streams of thought on design research and theory to provide a basis for a more systematic and useable formulation of these theories. We identify eight separate components of design theories: (1) purpose and scope, (2) constructs, (3) principles of form and function, (4) artifact mutability, (5) testable propositions, (6) justificatory knowledge (kernel theories), (7) principles of implementation, and (8) an expository instantiation. This specification includes components missing in the Walls et al. adaptation of Dubin (1978) and Simon (1969) and also addresses explicitly problems associated with the role of instantiations and the specification of design theories for methodologies and interventions as well as for products and applications. The essay is significant as the unambiguous establishment of design knowledge as theory gives a sounder base for arguments for the rigor and legitimacy of IS as an applied discipline and for its continuing progress. A craft can proceed with the copying of one example of a design artifact by one artisan after another. A discipline cannot.

Keywords: design theory, design science, constructive research, philosophy of science, information systems, information technology, artifacts, theory structure

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1. Introduction

It is difficult to over-emphasize the significance of design work and design knowledge in Information Systems (IS) for both research and practice. Theories for design and action continue to be highly influential in IS, despite the fact that they are not always recognized as theories. Some seminal examples include structured systems analysis (Gane and Sarson, 1979) and the Systems Development Life Cycle (SDLC) model. Design theories also give prescriptions for the architecture of specific applications, such as decision support systems (Turban and Aronson, 2001), a type of knowledge that forms a large part of curricula in IS, software engineering, and computer science education. Moreover, this knowledge has vital relevance to practitioners working with information systems. As van Aken (2004, p. 220) argues eloquently, one needs prescription-driven research that provides solutions for management problems in addition to description-driven research that enables us to understand the nature of problems but leaves undone the task of developing sound change programs. Increasing attention is being paid to this type of research in IS, notably by March and Smith (1995) and Hevner et al. (2004). The ISWorld website now has a section on design research with a current overview provided by Vaishnavi and Kuechler (2004/5). Some major issues, however, remain relatively unexplored.

One important issue is how design knowledge is captured, written down, and communicated. Herbert Simon in his seminal work, *The Sciences of the Artificial* (1996, p. 113), argued that we need a science of design that is "tough, analytic, partly formalizable, partly empirical, teachable doctrine." Making design science formalizable, at least in part, means that we need to pay attention to how design knowledge is expressed as theory. Gregor (2006) shows how design theory can be seen as the fifth in five classes of theory that are relevant to IS: (1) theory for analyzing, (2) theory for explaining, (3) theory for predicting, (4) theory for explaining and predicting, and (5) theory for design and action. The distinguishing attribute of theories for design and action is that they focus on "how to do something." They give explicit prescriptions on how to design and develop an artifact, whether it is a technological product or a managerial intervention. Of course, for this type of theory, as Hevner et al. (2004) show, we also need to consider epistemological questions of how knowledge is acquired and tested. This current essay, however, does not concern research methods or research approaches, important as they are, but the ontological components of the theory itself. We are taking a meta-theoretical view of the nature of design theories in IS in general. The aim of the paper is to show the structural components (the anatomy) that are needed to communicate a design theory.

The focus of the paper is on the anatomy of design theories in the discipline of IS, although much of the underlying literature in our discussion comes from a range of disciplines, and it is possible that our arguments have wider applicability. However, a characteristic that distinguishes IS from other fields is that it concerns the use of artifacts in human-machine systems. Lee (2001, p iii) uses these words:

Research in the information systems field examines more than just the technological system, or just the social system, or even the two side by side; in addition, it investigates the phenomena that emerge when the two interact.

Thus, we have a discipline that is at the intersection of knowledge of the properties of physical objects (machines) and knowledge of human behavior, and it is possible that IS design theories may take on a form different from those in other disciplines. The IS discipline is increasingly seen as one concerned with the design, construction, and use of artifacts based on information technology (IT), although the exact range and nature of the artifacts of interest is a matter of some debate (see Dahlbom, 1996; Orlikowski and Iacono, 2001; Benbasat and Zmud, 2003). The term *artifact* is used to describe something that is artificial, or constructed by humans, as opposed to something that occurs naturally (Simon 1996).

A central issue that must be acknowledged is that some researchers would argue with the use of the word "theory" for design-type knowledge, preferring to restrict the word to the possibly more familiar natural science (and, later, social-science) types of theory. Gregor (2006) highlights the differences in views on what constitutes theory, and shows that there are both proponents and opponents for the five types of theory she identifies. With respect to theory for design and action, Simon (1996) is the well-recognized proponent of this form of theory, and others have followed his lead (Iivari, 1983; Markus et al., 2002; Walls et al., 1992). Van Aken (2005) uses the term "Management Theory" for prescriptive, solution-oriented knowledge that encompasses "technological rules," while distinguishing more description-oriented knowledge as "Organization Theory." Otherwise, there is some feeling against recognizing design principles as theory. March and Smith (1995) and Hevner et al. (2004) promote design science as a research activity, but tend to reserve the word "theory" for natural science-type research (Type 3 and 4 theory in Gregor, 2006). The seemingly different views may, in part, be semantic and depend on individual views of what is meant by theory, as outlined above. We adopt a broad view of theory, congruent with Gregor (2006) and the OED (2004), which means that the term theory encompasses what might be termed elsewhere conjectures, models, frameworks, or bodies of knowledge—terms that are used in connection with design science by many authors. For example, Hevner et al. (2004), see "constructs, models and methods" as three of the four outputs of design science, with the "artifact" being the fourth. A broader view of theory means that the first three outputs are regarded as components of theory.

We believe that it is of vital importance to investigate how design knowledge can be expressed as theory (see also Purao, 2002; Rossi and Sein, 2003; Vaishnavi and Kuechler, 2004/5), although some might argue that the benefits of design research can be enjoyed without the need for theories of design. The weakness of this latter view is demonstrated by Cross (2001, p. 4), who deals comprehensively with the idea of design as a discipline. Cross shows how at one level design work can proceed without reflection on theory:

> We must not forget that design knowledge resides in products themselves: in the forms and materials and finishes which embody design attributes. Much everyday design work entails the use of precedents or previous exemplars – not because of laziness by the designer but because the exemplars actually contain knowledge of what the product should be. This is certainly true in craft-base design: traditional crafts are based on the knowledge implicit within the object itself of how best to shape, make and use it. This is why craft-made products are usually copied very literally from one example to the next, from one generation to the next.

However, we would prefer that IS rise above the level of a craft and agree with Cross, who says that in addition to this informal product knowledge, we need for design research: "the development of more formal knowledge of shape and configuration – **theoretical** studies of design morphology" (p. 5, emphasis added).

Seeking to express IS design knowledge as theory provides a sounder basis for arguing for the rigor and legitimacy of IS as an applied discipline, in comparison with the older, more traditional disciplines in the natural sciences, which use a complementary, but different paradigm.[1] Our own experience has shown how both students and more experienced researchers struggle with the problem of expressing design knowledge in an acceptable form in theses and journal articles. Better understanding of the nature of design theory provides an avenue for the more systematic specification of design knowledge.

Furthermore, understanding the nature of IS design theories supports the cumulative building of knowledge, rather than the re-invention of design artifacts and methods under new labels in the waves of "fads and fancies" that tend to characterize IS/IT. As an example, the basic problem of understanding how to capture the tacit knowledge of experts remains much the same whether it is studied for expert systems or knowledge management systems, and whatever the application domain. Our design theories should be classified and compared under the most general statement of the problem being addressed that can be found (the purpose and scope of the theory), for example, "capturing tacit knowledge from experts in organizations." A claim for a better theory must show that the new theory provides an advance

[1] This issue is one also for many other applied disciplines such as accounting, education, management marketing, engineering, and other fields of information technology.

on all previous methods for solving this problem, no matter in which disciplinary sub-field they have been proposed. Again, personal experience has shown that this requirement is not well understood by many authors and this shortcoming results in a common cause for journal papers being rejected: not making a sufficient theoretical contribution.

As an initial introduction to the idea of design theory structure, Table 1 shows how our proposed anatomy of a design theory can be detected in Codd's articles introducing the relational database model. This anatomical skeleton, consisting of eight fundamental components, is what we derive more thoroughly in the remainder of this essay.

Table 1: Example of the skeleton of a design theory (from Codd, 1970, 1982)

Article details	The design theory anatomy
The introduction says better database technology is needed to increase human productivity. (Motivation is also provided: This need is significant because current approaches are failing.)	The **purpose and scope** of the theory are stated.
The relational database model has principles such as "the order of rows in the tables is arbitrary and irrelevant."	**Principles of form and function** incorporating underlying **constructs** (such as "table") are given.
The argument is made that the relational model allows for relatively simple adaptation and change to base tables, while user views appear unchanged.	**Artifact mutability** is addressed.
Statements are made such as "A relational database can perform as well as a non-relational database."	These statements are **testable propositions.**
It is shown how the relational model works, by reference to underlying set theory and also human cognitive processes.	**Justificatory knowledge** (kernel theory) is provided.
Guidelines are given on how to produce a relational database through normalization procedures.	**Principles of implementation** are given.
An illustration of working relational databases is provided.	An **expository instantiation** is given.

The anatomy of design theories has received relatively little critical attention. Walls et al. (1992, p. 36) made a valuable initial attempt at this problem and we build on this work. Walls et al. defined an information systems design theory (ISDT) as "a prescriptive theory which integrates normative and descriptive theories into design paths intended to produce more effective information systems." In 2004 Walls et al. provided a retrospective on the fate of their ISDT formulation, and they expressed some disappointment about what they saw as its limited use. They wondered if their specification was too unwieldy or cumbersome for general use, or too difficult to grasp, and concluded that their ISDT required "much more work in being complete and in making the exposition more palatable" (p. 55). We agree that it is timely to consider whether improvement in their specification model is possible.

The primary sources drawn upon by Walls et al. in their 1992 paper were Dubin's (1978) depiction of theory of the natural science type and Simon's (1981) depiction of the sciences of the artificial. Perhaps not surprisingly, given the novelty of their endeavour and the dual aims of their article, these authors did not capture fully the range of ideas offered by Dubin and Simon, or ideas that have been presented in other important related work. Two of Dubin's mandatory theory components are missing from the Walls et al. specification. These components are the "units," the constructs that are the basic building blocks of theory, and "system states," the range of system states that the theory covers. The problem of specifying a theory for methodologies as opposed to a theory for a product was not explicitly addressed, and their formulation had some unnecessary complexity in that it required kernel theories for design product and design process to be separated. Furthermore, Walls et al. (2004) themselves wondered if their depiction of design theory components was too unwieldy for use. They looked at the comparatively few articles that had explicitly referred to their formulation of ISDT, but did not consider the continuing over-arching tradition of presenting design-type work in our IS journals (see Gregor, 2006; Morrison and George, 1995; Orlikoski and Iacono, 2001), where there are alternative forms. The structures implicit in other design-type work in this substantial history give clues as to what might be more familiar and more useable ways of presenting design theories.