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A Framework for Theory Development in Design Science Research: Multiple Perspectives

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Abstract

One point of convergence in the many recent discussions on design science research in information systems (DSRIS) has been the desirability of a directive design theory (ISDT) as one of the outputs from a DSRIS project. However, the literature on theory development in DSRIS is very sparse. In this paper, we develop a framework to support theory development in DSRIS and explore its potential from multiple perspectives. The framework positions ISDT in a hierarchy of theories in IS design that includes a type of theory for describing how and why the design functions: Design-relevant explanatory/predictive theory (DREPT). DREPT formally captures the translation of general theory constructs from outside IS to the design realm. We introduce the framework from a knowledge representation perspective and then provide typological and epistemological perspectives. We begin by motivating the desirability of both directive-prescriptive theory (ISDT) and explanatory-predictive theory (DREPT) for IS design science research and practice. Since ISDT and DREPT are both, by definition, mid-range theories, we examine the notion of mid-range theory in other fields and then in the specific context of DSRIS. We position both types of theory in Gregor's (2006) taxonomy of IS theory in our typological view of the framework. We then discuss design theory semantics from an epistemological view of the framework, relating it to an idealized design science research cycle. To demonstrate the potential of the framework for DSRIS, we use it to derive ISDT and DREPT from two published examples of DSRIS.

Keywords: *Design Science Research, Theory Development, Mid-Range Theory, Framework.*

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A Framework for Theory Development in Design Science Research: Multiple Perspectives

1. Introduction

It has taken more than 350 years, from Francis Bacon (1994/1620) to Karl Popper (1989), to define and refine the Western scientific notion of "theory". Shelves of books (Dubin, 1978, is an example well known to IS Ph.D. students) and reams of academic publications have been written in an attempt to define theory and evolve methods for its creation. Gregor (2006) recently published an already widely cited paper just on the single aspect of identifying types of theory in IS. We give this prelude to provide perspective on the limitations of any single paper in the area of theory development. Our goal is not to define theorizing in design science research in IS (DSRIS) but rather to move a step toward that goal by describing a framework for theory development in DSRIS and providing some simple illustrations of its use.

2. Design Science Research in IS (DSRIS) Defined

In this paper, we use the term DSRIS to indicate IS research that uses artifact design and construction (learning through building) to generate new knowledge and insights into a class of problems[1]. Our framework for theory development in DSRIS makes minimal requirements on the method by which DSRIS is accomplished. It requires three general activities: (1) construction of an artifact where construction is informed either by practice-based insight or theory, (2) the gathering of data on the functional performance of the artifact (i.e., evaluation), and (3) reflection on the construction process and on the implications the gathered data (from activity (2)) have for the artifact informing insight(s) or theory(s). The definition of IS artifact used in this discussion is the ensemble view from Orlikowski and Lacono (2001) and is very broad, including software, composite systems of software, users and use processes, and IS-related organizational methodologies and interventions.

Table 1. An Acronym Quick Reference

Acronym	Expansion	Definition
DSRIS	Design science research in information systems	A research methodology in the Information Systems discipline in which new knowledge is produced by the construction and evaluation of "artifacts", broadly defined as software, composite systems of software, users and use processes, and IS-related organizational methodologies and interventions. Key elements distinguishing DSRIS from behavioral IS research are: the ability to explore new, as yet un-theorized areas, constructivist rather than statistical methods and, as suggested in this paper, the ability to build as well as test theory.
ISDT	Information systems design theory	As initially introduced by Walls, Widmeyer, and El Sawy (1992, 2004), an ISDT is a set of primarily prescriptive statements describing how a class of artifacts should behave (meta-requirements) and how they can be constructed. Recently, suggestions have been put forth for expanding the scope of design theory to include more "justificatory knowledge", or information indicating why the artifact behaves as it does (Gregor & Jones, 2007).
DREPT	Design relevant explanatory / predictive theory	A type of theory suggested in this paper that augments the "how" information content of the traditional ISDT statement with explanatory information explaining why the artifact has the effects it does. The explanatory information may borrow theoretical information from the natural, social, or design sciences. DREPT is similar to but more formally stated than the "justificatory knowledge" proposed as an addition to ISDT.

[1] We term the study of the act of design itself and of designers "design research" (DR – without the word "science"). We consider both to be valued directions in IS research; however, DR is tangential to the subject of this paper.

Within the framework developed here there are three potential outputs of a DSRIS project: (1) an artifact, (2) an information systems design theory (ISDT), and (3) Design relevant explanatory/predictive theory (DREPT). An artifact, in the broad definition given above, is mandatory. ISDT and DREPT are optional; the development of either or both for a DSRIS project depends on the details of the project and the intention of the researchers. In the DSRIS community, several structures for ISDT have been proposed, as explained in more detail in a following section of this paper. In each case, however, an ISDT captures design information on the class of artifacts of which the specific artifact created in the DSRIS project is an expository instantiation. An expository instantiation is a part of the Gregor and Jones (2007) structure for an ISDT and serves as both a proof of concept of the ISDT and, in many cases, as the most readily comprehensible illustration of the ISDT (e.g., screen shots of a prototype). Many recent published examples of DSRIS (Hall, Paradice, & Courtney, 2003; Jones & Gregor, 2006; Markus, Majchrzak, & Gazzer, 2002) have included an ISDT, and we believe this to be an increasing trend.

A formal definition of DREPT is a novel contribution of this paper, which we develop in later sections of the paper. However, the equivalent of DREPT (or its functionality) has been informally described in several papers (Gregor & Jones, 2007; Kuechler & Vaishnavi, 2008b; Sein, Henfridsson, Purao, Rossi, & Lindgren, 2011). DREPT explains how and why the artifact functions as it does; specifically, it explains how novel artifact design features have the effects they do.

The three general activities of DSRIS methods required by our framework are consistent with all the most widely cited discussions of such methods (Gregor & Jones, 2007; Hevner, March, Jinsoo, & Ram, 2004; March & Smith, 1995; Nunamaker, Chen, & Purdin, 1991; Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007; Vaishnavi & Kuechler, 2009; Walls et al., 1992). We note that March and Smith (1995), Hevner et al. (2004), and Peffers et al. (2007) are moot on general activity (3), that is, they do not explicitly mention reflection but certainly do not preclude it. In fact, the activity of reflection simply adds an additional, compatible step to any published DSRIS methodology.

Recently Sein et al. (2011) proposed a new method for design science research in IS called action design research. Action design research, as we understand it, differs from traditional design science research by requiring on-organizational-site artifact implementation and evaluation so that the artifact emerges from both the designer/researcher vision and interaction of the artifact and its designers with the organizational environment. The emergence takes place in the building, intervention, and evaluation phase of the research, during which “the problem and the artifact are continually evaluated”. Though novel in some aspects, action design research explicitly prescribes all three of the general activities in our framework for theory development requires. In fact, formalization of learning, as Sein et al. define it, is exactly our general activity (3) above: “These outcomes [from artifact implementation] can be characterized as design principles [ISDT] and with further reflection, as refinements to theories that contributed to the initial design [DREPT]” (Sein et al., 2011, p. 44).

As DSRIS has matured, the stress has increasingly shifted from the artifact itself to the abstracted requirements and methods for its design as primary deliverable from a DSRIS effort (Gregor & Jones, 2007; Kuechler & Vaishnavi, 2008a). The most commonly understood form for this directive information is termed a design theory (ISDT – information systems design theory) for the class of artifacts of which the specific artifact in the DSRIS project is an instantiation (Walls et al., 1992, 2004). Walls et al. suggested a specific format for an ISDT, and many DSRIS exemplars (Hall et al., 2003; Jones & Gregor, 2006; Markus et al., 2002) have followed this definition to varying degrees. Table 2 provides a template indicating the components of an ISDT.

The ISDT of Table 2 is broadly divided into description of the functionality of a class of artifacts – the meta-requirements and meta-design of the design product – and the techniques for creation of an instance of the class – the design method of the design process. Both design product and design process may specify kernel theories, typically defined as “natural science theories from other disciplines” (March & Smith, 1995) that suggest either the meta requirements or the construction process. Following more recent published design science examples (Arnott, 2006; Iverson, Mathiassen, & Nielsen, 2004; Sein et al., 2011), we have broadened the scope of kernel theories to include social and design science theories as well as natural science (e.g., physics, psychology) theories. The format of the ISDT content as logical statements – of functionality, design specifications, methods, and tests for these (the design hypotheses) – makes it apparent that an ISDT is by its nature and intent, prescriptive[2]. An ISDT is similar to what is called a model in computer science and some engineering disciplines (Evbuowan, Sivaloganathan, & Jebb, 1996); it provides high level definition of the functioning of an artifact to achieve a design goal and direction toward its construction, but does not describe how the artifact works or by what mechanism(s) the meta requirements and design method achieve the design goal.

Table 2. Content Categories of Information System Design Theory (from Walls et al., 2004)

		Theory Component of ISDT
Design product	1.	Meta-requirements
	2.	Meta-design
	3.	Kernel theories
	4.	Testable design product hypotheses
Design process	1.	Design method
	2.	Kernel theories
	3.	Testable design process hypotheses

Although kernel theories are suggested components of an ISDT, the Walls et al. (1992, 2004) ISDT framework is moot as to how the kernel theory relates to or suggests the prescribed design. A more abstract type of design relevant explanatory/predictive theory (DREPT) is required to capture that knowledge. We propose that in many cases this information can be as valuable to the cumulative work of IS researchers in an area as the artifact or the ISDT itself. Beyond content, we will show that DREPT is a useful formalism in a framework for theorizing in DSRIS; it provides a logical step that bridges the conceptual distance between kernel theory constructs and artifact features. This conceptual distance is a near synonym for the "creative leap" in DSRIS, from theory to artifact, which has proven so confounding to those from research traditions more centered in formal logic who attempt to understand DSRIS.

3. A Knowledge Representation Perspective on the Framework

As the logical entry to our framework for theory development in DSRIS, we explicitly represent ISDT and DREPT as knowledge representations, each capturing a different sort of design-related knowledge; this is illustrated in Figure 1. In a later section, we discuss theory generation with respect to specific phases in the progression of a design science research project; for now we note simply that under our framework there is an evolution and translation of DSRIS knowledge from general explanatory or predictive constructs to the design features of an IS/IT artifact. The explanatory or predictive knowledge may originate in kernel theories or in experience-based insights (evidence-based justification), but it always exists; to suggest otherwise is to imply design is a random process. Note that ISDTs and DREPTs are mid-range theories, conceptual intermediaries between the highly abstract space of potential problem solutions suggested by kernel theories or insights and the concrete problem solution of the implemented artifact. The arrows of Figure 1 represent logical progression – from highly abstract notions through their progressive concretization to the physical artifacts themselves. As we will discuss in a later section, the actual process of knowledge translation and development in DSRIS may also proceed inductively (from right to left in Figure 1) as well as deductively/abductively (from left to right in Figure 1) or along both paths.

[2] To avoid a common misunderstanding, we note a difference between the terms prescriptive and normative. A prescription suggests action in a given circumstance in order to achieve an effect. Prescription does not imply logical completeness, that is, it makes no claim that it is the only action available in the circumstance to achieve the effect, nor does it imply, as a normative statement does, an imperative, an ought, that suggests this action and only this action is appropriate for achieving the effect in the given circumstance.

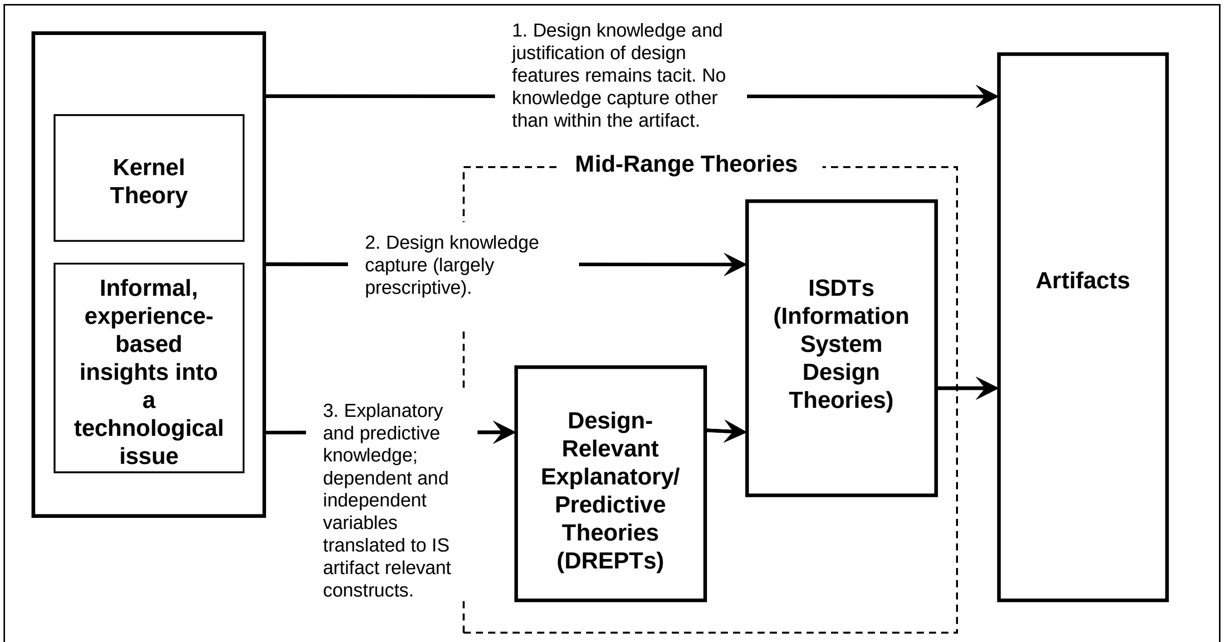

Figure 1. ISDTs and Design-Relevant Explanatory/Predictive Theories (DREPT) as Mid-Range Knowledge Representations in Design Science Research

Arrow 1 in Figure 1 represents design science research in IS that is pre-ISDT and as it is still occasionally seen in fields such as engineering and computer science. An artifact is designed and implemented as a solution to a problem addressable through technology. However, in an Arrow-1-type presentation of design science research, the artifact stands or falls on its own merits; there is no discussion of how the artifact features achieve the desired effects or even of the design techniques used in its construction. This method of doing design science research works best for truly groundbreaking innovations where the artifact presented is a singular, immediately useful contribution. Entity-relationship modeling for databases (Chen, 1976) is the classic example of this sort of design science research.

Arrow 2 in Figure 1 is indicative of the current state of DSRIS. The seminal insight in Walls et al.'s (1992) development of an ISDT was that the work done in creation of a problem-solving artifact would be much more valuable to both research and practice by formally codifying the design effort. Without this codification (in an ISDT) the requirements for the artifact and the method of its design would have to be explicated from a description of the artifact and/or from observation of its working. For practitioners, such level of effort is frequently too great to attempt. Even for researchers with a dedicated interest in the research area, deconstructing artifact performance to understand design principles and requirements is a difficult and time consuming duplication of effort. A second valuable principle in the Walls et al. (1992, 2004) conception of an ISDT is abstraction: rather than codifying the design for a specific artifact implementation, an ISDT captures meta-requirements and a meta-design that are applicable to a class of artifacts. The specific implementation resulting from the DSRIS project is just one example of the class.

Arrow 3 of Figure 1 illustrates the knowledge translation in the course of DSRIS using a second mid-level representation, design relevant explanatory/predictive theory (DREPT). DREPT extends the two insights that motivated ISDT. First, it captures knowledge generated during a design science research project that is not captured in an ISDT: the translation of highly abstract constructs from natural, social or design sciences fields to the realm of artifact-achievable effects. By linking effects, the causes of which are explained by the kernel theory, with design features, the DREPT explains how and why a design based on the DREPT achieves its desirable novelty. ISDT, by contrast, is almost exclusively concerned with implementation: What and how to build (meta-requirements and meta-design). Kernel theories are mentioned as having a relationship to the design, but no guidance on their refinement to design principles is given.

Second, DREPT is more abstract than ISDT and is, therefore, more broadly applicable. A DREPT captures knowledge that can be useful in the design of multiple classes of artifacts related by a common desirable effect (e.g., increased user attention to displayed information). Design science researchers typically pursue knowledge in and of a field – explanatory and predictive understanding of the field as well as seeking to provide concrete solutions to problems in that field – artifacts. DREPT can provide the means to build such an explanatory and predictive knowledge base.

To clarify the translation from kernel theories to DREPT (Arrow 3 in Figure 1), consider a concrete example of a DREPT and the way in which it is developed. The example is a design science research project to improve recommender systems, such as the one used by Amazon to suggest book choices[3]. In the course of the project, during the researching of prior work on the subject, a number of potentially useful theories from social psychology, consumer research, and related fields are identified. These theories are broad explanatory theories (kernel theories) of advice taking and trustworthiness of information, and they have no relationship to recommender systems or to technology in any form. The contribution they may have to enhanced recommender system design is, thus, "gut level" and highly nebulous. Therefore, before proceeding to design the recommender system (artifact), the researchers feel it would be beneficial to derive, from the kernel theories they have identified, a technology-focused theory of advice taking to guide their design efforts. This mid-range theory maps kernel theory causes of increased trustworthiness of information – typically information from specific sources – to specific information types available in a networked technology, such as e-relationship information. The theory further maps kernel theory effects – increased trust in information supplied – to technology artifact effects, such as increased usage of information supplied by recommender or other technological systems. By these mappings, the researchers have created from broad, technology-free theory, a design related mid-range theory that can explain why a designed technological artifact that makes use of certain types of information for advising user choice has the effect of increased believability. Note that this mid-range theory, a DREPT as we have defined it, has the characteristic we suggest for such theory of being broad enough to directly assist in the design of multiple classes of artifacts, such as on-line advertising systems or dating services such as e-Harmony, in addition to assisting in the design of recommender systems. We give two more detailed examples of the translation of kernel theory to DREPT in the last third of this paper.

4. Extending Knowledge Capture in DSRIS: Alternative Approaches

Gregor and Jones (2007), working from seminal discussions of theory and design that have taken place over 2,500 years, revisit Walls et al.'s (1992, 2004) ISDT definition. Their analysis both provides a valuable "unpacking" of the theory components of Table 2 and suggests extensions, such as artifact mutability and justificatory knowledge that bring the Walls et al. (1992, 2004) definition of ISDT closer to traditional conceptions of descriptive or explicating theory as contrasted to its current highly prescriptive form. We view Gregor and Jones' discussion as a call to DSRIS researchers to capture more of the knowledge generated in a DSRIS effort than is possible in the Walls et al. (1992, 2004) definition of an ISDT. This is precisely our position; certainly our efforts are complementary to Gregor and Jones.

However, while they propose extending knowledge capture by extending the definition of an ISDT, we propose keeping the Walls et al. definition of ISDT as almost purely prescriptive and extending knowledge capture with the addition of DREPT. We justify this on several grounds: First, we observe that the ISDT of Walls et al. (1992, 2004) is currently more familiar to the majority of DSRIS practitioners (March & Storey, 2008) and since that ISDT definition guided many past exemplars of DSRIS (Adomavicius, Bockstedt, Gupta, & Kauffman, 2008; Kasper, 1996; Markus et al., 2002; Pries-Heje & Baskerville, 2008), it allows us to make highly informative cross-study comparisons. Second, we propose that two distinct modes of knowledge capture intended for quite different purposes – a

[3] This example draws heavily from an actual example of kernel theory refinement in Arazy, Kumar, & Shapira (2010).

prescriptive ISDT to capture low-level (construction) design knowledge and DREPT to capture artifact-relevant explanatory-predictive knowledge – are more comprehensible and do not overburden the already “busy”, multifaceted Walls et al. information representation. Baskerville and Pries-Heje (2010) directly question the “layering of complexity” in expressions of design theory like that in the Walls et al. (2004) ISDT. Indeed, Walls et al., in their 2004 reflection on ISDT (as cited in Gregor & Jones, 2007), explore the possibility that the ISDT as they originally conceived it (Table 2) was too unwieldy and ad-hoc to be widely accepted and used.

The difference between Gregor and Jones’ (2007) approach and our approach to capturing design science research knowledge is probably less than what may appear initially. Gregor and Jones’ discussion of the justificatory knowledge component they propose to add to ISDT (pp. 327-328) includes much of the explanatory knowledge we propose be captured in DREPT. They describe it as “knowledge of how material objects behave so as to judge their capabilities for a design”, and liken it to the kernel theories presented by Walls et al. (1994, 2004). However, for Gregor and Jones, beyond merely being referenced, these theories should be logically linked, as much as is possible, to designed attributes via a discussion of why the artifact functions as it does. It is evident from their discussion that we and Gregor and Jones share a strongly held belief that the knowledge presented about a DSRIS project should explain how and why the design works in addition to explaining how to replicate it. Our DREPT may simply be a more formal version of their justificatory knowledge ISDT component. However, as we will show, the formality of DREPT is useful in our framework for theorizing in DSRIS.

Arazy, Kumar, and Shapira (2010) suggest an approach to theory development in DSRIS that has parallels to, but does not duplicate, our framework. They share our belief (as do Gregor & Jones, 2007) that kernel theories are at such a high level of abstraction that their relationship to design and suggestions for design are frequently difficult to discern. Further, they share our understanding that the Walls et al. (1992, 2004) ISDT framework is inadequate to explicate design-related knowledge from kernel theories. To bridge the gap – to effect the linkage between kernel theories and design – Arazy et al. (2010) propose the development of what they term applied theories. Applied theories, in their understanding, are derived from kernel theories but address two major issues in linking kernel theory and design. First, the narrow scope (typically) of kernel theories frequently necessitates the use of multiple kernel theory frameworks to explain a single design feature. Second, the granularity of constructs in kernel theories is (frequently) inappropriate to design because the constructs do not map easily to design goals. Arazy et al. clarify this by saying “Although we cannot expect to find a direct one-to-one mapping [between constructs and design goals] the correspondence should be clear”.

To address these problems, Arazy et al. (2010) construct their applied theory by first identifying significant, potentially improvable facets of a problem-solving artifact. Second, they determine themes or unifying factors from prior (high-level theoretical) research that grounds each of the artifacts’ facets. The factors then become the constructs for the applied theory. Since the factors were identified from theory frameworks chosen for their relevance to artifact facets, they are at the appropriate granularity and map easily to artifact goals. The constructs of the original kernel theory frameworks are now the internal structure of each applied theory factor and generate specific, testable hypotheses concerning the applied framework.

The primary similarity between the theory refinement approach set out in Arazy et al. (2010) and the one developed in this paper lies in the explicit attempt to strongly link kernel theory constructs with design facets. The approaches differ in that: (1) the applied theory of Arazy et al. remains in the area or discipline of the kernel theories from which it was derived, whereas the DREPT we propose is firmly in the design domain; (2) their approach is, by definition, a priori; it takes place prior to any design effort, while our framework accommodates both a priori theorizing and reflective, inductive, after the fact theory development; (3) the multiple perspectives developed for our framework give it a more solid grounding in design science and an extended rationale; (4) Arazy et al. limit themselves to "applied behavioral theory"[4], whereas our framework explicitly accommodates kernel theories from behavioral, physical (natural), or design sciences.

5. Paper Structure

In Section 6, we present the notion of mid-range theory from other fields of study, and, in Section 7, elaborate on the nature and value of DREPT and ISDT from the perspective of Gregor's (2006) taxonomy of IS theory (a typological view of our framework). In Section 8, we present an epistemological perspective of the framework and relate it to specific activities in the design research activity cycle. Throughout these discussions, abstract points are related to aspects of concrete projects (Kasper, 1996; Kuechler & Vaishnavi, 2008b; Vaishnavi & Kuechler, 2009). In Section 9, to demonstrate the utility of the framework, we extend several published examples of DSRIS with proposals for mid-range theories that derive logically from the constructs in the kernel theories and the design theories of the examples. The place of theory development in DSRIS (and in IS in general) is still debated among DSRIS researchers, and, in the conclusion, we briefly discuss some of the cultural issues that figure in the debate, and summarize our contribution.

6. Mid-Range Theory in DSRIS

Thomas Merton, the influential social scientist who introduced the concept of mid-range theory, gave the following definition for mid-range theories: "Theories that lie between the minor but necessary working hypotheses that evolve in abundance during day-to-day research and the all-inclusive systematic efforts to develop a unified theory" (Merton, 1968). Gregor (2006), in her exposition of theory in IS, uses the degree of "generalization" of a theory as one taxonomic principle: Mid-range theories have the characteristics of being "moderately abstract and limited in scope." Gregor also notes that one of the characteristics of mid-range theory, highly valued in all sciences, is that it easily leads to testable hypotheses. This is true for both ISDT and DREPT in their respective realms of artifact construction and artifact-effect understanding.

Unlike the management, medical, sociology, and even engineering literatures, where mid-range theories are frequently specifically titled as such (i.e., "A mid-range theory of _____"), a search through IS literature databases reveals only two papers that explicitly present their findings as mid-range theory: Nelson, Nadkarni, Narayanan, and Ghods (2000) and Kuechler and Vaishnavi (2008b). However, mid-range theories are common in IS[5]. In fact, though we cannot digress to do so here, a logical case can be made that most IS theories[6] are mid-range, since IS is an applied discipline with a history of drawing from more fundamental disciplines. An example familiar to most IS researchers is the theory of cognitive fit (Shaft & Vessey, 2006). Cognitive fit theory is essentially the specialization to the technology domain of aspects of multiple theories from cognitive science. Its constructs are constrained and specialized relative to those of the originating or suggesting theories; and because cognitive fit is constrained to the technology domain, specialized claims concerning that domain can be proposed. The translation/specialization of constructs from a general theory to a more tightly scoped domain is one key principle of our framework for theory construction.

Most discussions about mid-range theory also make a distinction between substantive theory and formal theory (Bourgeois, 1979; Gregor, 2006; Merton, 1957). Substantive theory is "developed for a specific area of inquiry, such as delinquent gangs, strikes, divorce…" (Gregor, 2006). In DSRIS substantive theory could be induced from performance data on an artifact when it is operated in a specific context. Formal theory, in contrast, has explanatory power across specific areas and operates in that sense at a higher level of abstraction. DREPT, as we conceive it, (Figure 1) is formal theory in this sense.

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[4] We feel the approach set out in Arazy et al. (2010) is quite general even though they limit themselves in the paper to applied behavioral theories.

[5] We are indebted to the AE for pointing this out.

[6] Note the distinction between theories used in IS and IS theories. The theories most widely used for research in IS are from outside the IS domain – see http://www.fsc.yorku.ca/york/istheory/wiki/index.php/Main_Page#Contributions. IS theories are those developed specifically for use in IS.

In some early discussions of mid-range theory from qualitative fields (Bourgeois, 1979) mid-range theory building was suggested to be an inductive exercise: Induction from field data gave substantive theory; induction and pattern matching from substantive theories yielded formal theory. However, in many fields – management, medicine, and engineering for example – mid-range theory building has a deductive character, moving explicitly from a general explanatory/predictive theory to a specialized, environment-constrained, mid-range theory expression (Hitt & Ireland, 1994; Nolan & Grant, 1992; Stone & McKenry, 1998). Both deductively derived and inductively derived mid-range theories in all fields have the function of "linking" conceptual levels (Raab & Goodyear, 1984). However, deductively derived mid-range theory typically has a distinct starting point in a broadly based theory of a certain phenomenon; that general theory is then made more specific to accommodate empirical data taken from a sub-range of the phenomenon covered by the general theory. Our framework specifically accommodates this type of theory building in DSRIS where kernel theories provide the general constructs.

7. Typological Perspective of the Framework

As discussed in the introduction, the difference between ISDT and DREPT is, in essence, the difference between how to construct an artifact (ISDT) and how/why the artifact features have the desired effects (DREPT). The following discussion illustrates those differences. Figure 2 provides a typological perspective of the framework and illustrates the relationships between kernel theories, ISDT, and DREPT within Gregor's (2006) typology of IS theory.

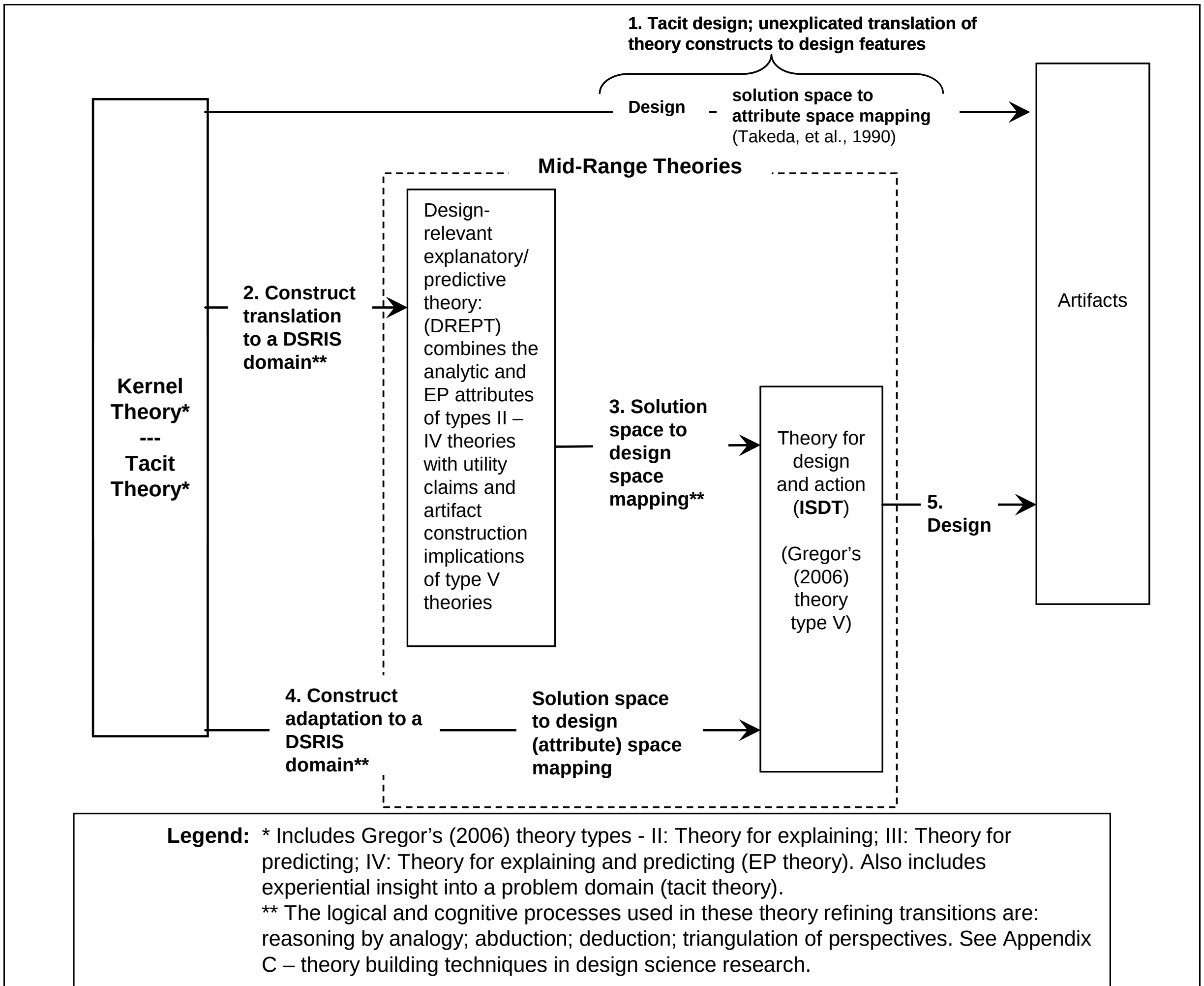


Figure 2. Relationships Between Gregor's (2006) Theory Types, DREPT, ISDT, and DSRIS Artifacts. Adapted from Gregor (2006) and Venable (2006)

As in Figure 1, the arrows in Figure 2 represent logical progression – from highly abstract notions through their progressive concretization to the physical artifact itself[7]. On the left of Figure 2 are theory types II through IV, which are not constrained to design and action: They are theory as it is traditionally understood in the physical and social sciences. To these we have added an additional type theory – tacit theory – for completeness in the DSRIS context; insights or evidence/experience-based justifications for pursuing a novel design. This theory type is informal and is frequently not explicitly stated, but is very important to DSRIS in that such theories provide design science research with the ability to explore areas where formal theory is sparse or non-existent[8]. The construction and operation of an artifact designed with tacit grounding yields data on which substantive theory can be based, allowing formal understanding to be bootstrapped from field-based evidence and intuitions.

At the far right of Figure 2 lie the most concrete results of a DSRIS project, the functioning, testable, observable artifact. Between the more abstract theory types on the left and the artifact are the two types of mid-range DSRIS theory that make explicit the knowledge that is implicit in the artifact. The first type of mid-range theory is design theory (ISDT), which Gregor (2006) also calls type V: "Theory for design and action". In this paper we assume that type V theory has the expression shown in Table 2, which is described in detail in Walls et al., (2004). Venable (2006) makes a strong case that in addition to design information, design theory (ISDT) necessarily makes utility claims; these are of the form: If you construct an artifact according to this design specification and follow this design process, this useful result will ensue.

The second type of information systems design theory in Figure 2 is what we have termed design-relevant explanatory/predictive theory (DREPT). As implied by the figure, DREPT constructs are type II-IV theory constructs constrained to (specialized for) the design domain. They too make utility claims, but at a more abstract level than type V theory. The utility claim of a DREPT is: This useful effect is realized by these lower level phenomena, and so any artifact that implements these phenomena will achieve this effect. We are now in a position to more formally define DREPT. As implied in the above discussion, we envision DREPT in DSRIS not as generalized type V theory (theory for action) but rather as:

(a) A type II-IV (explanatory/predictive) theory (using Gregor's (2006) typology)

(b) Derived from a highly abstract covering theory (kernel theory) that originated in a non-design domain or tacit theory

(c) But in which the kernel or tacit theory constructs have been translated into a technology domain.

We cover the translation from kernel theory dependent variable (DV)/independent variable (IV) to DREPT theory DV/IV below and give several examples in a subsequent section of the paper. Here, it is important to note that with the dependent variable (DV(s)) and independent variable (IV(s)) of the theory statement clearly in the technology domain, DREPT comes very close to having an action-implication aspect, per Gregor's (2006) type V theory[9]. That is, a design science researcher exploring the DV set forth in a DREPT can much more readily make associations between the DV and technology artifact design parameters than when working from kernel theory.

[7] We wish to emphasize that the progressive concretization of theory constructs that is diagrammed in Figure 2 does not represent the workflow or activity flow of a DSRIS project. DSRIS methodologies instead follow roughly the flow of Figure 4. See also Peffers et al. (2007) and Vaishnavi and Kuechler (2008b). We are indebted to Shirley Gregor (personal communication) for helping us to clarify this difference.

[8] Hevner et al. (2004, p. 99) state: "The existing knowledge base is often insufficient for design purposes and designers must rely on intuition, experience and trial-and-error methods".

[9] An explanatory/predictive theory (Gregor's (2006) types II-IV) traditionally has the form: "IF A (B, C, . . .) THEN D (E, F, . . .)" (Lee & Hubona, 2009). The output of design science research (following Bunge, 1984) is a technological rule: A chunk of general knowledge, linking an intervention or artifact with a desired outcome of performance in a certain field of application (van Aken, 2004). In DSRIS, we term a specific format for these technological rules an ISDT. The logical format of this technological rule is: "IF YOU WANT TO ACHIEVE Y IN SITUATION Z, THEN SOMETHING LIKE ACTION X WILL HELP". van Aken (2004) continues, "'Something like action X' means that the prescription is to be used as a design exemplar… The indeterminate nature of a heuristic technological rule makes it impossible to prove its effects conclusively, but it can be tested in context, which in turn can lead to sufficient supporting evidence".

8. Epistemological Perspective of the Framework

Figure 3 illustrates the relationship of theory levels to the semantics of each level and to the iterative practice of DSRIS. Figure 3 draws heavily from Goldkuhl's (2004) epistemological examination of knowledge generated in the course of DSRIS.

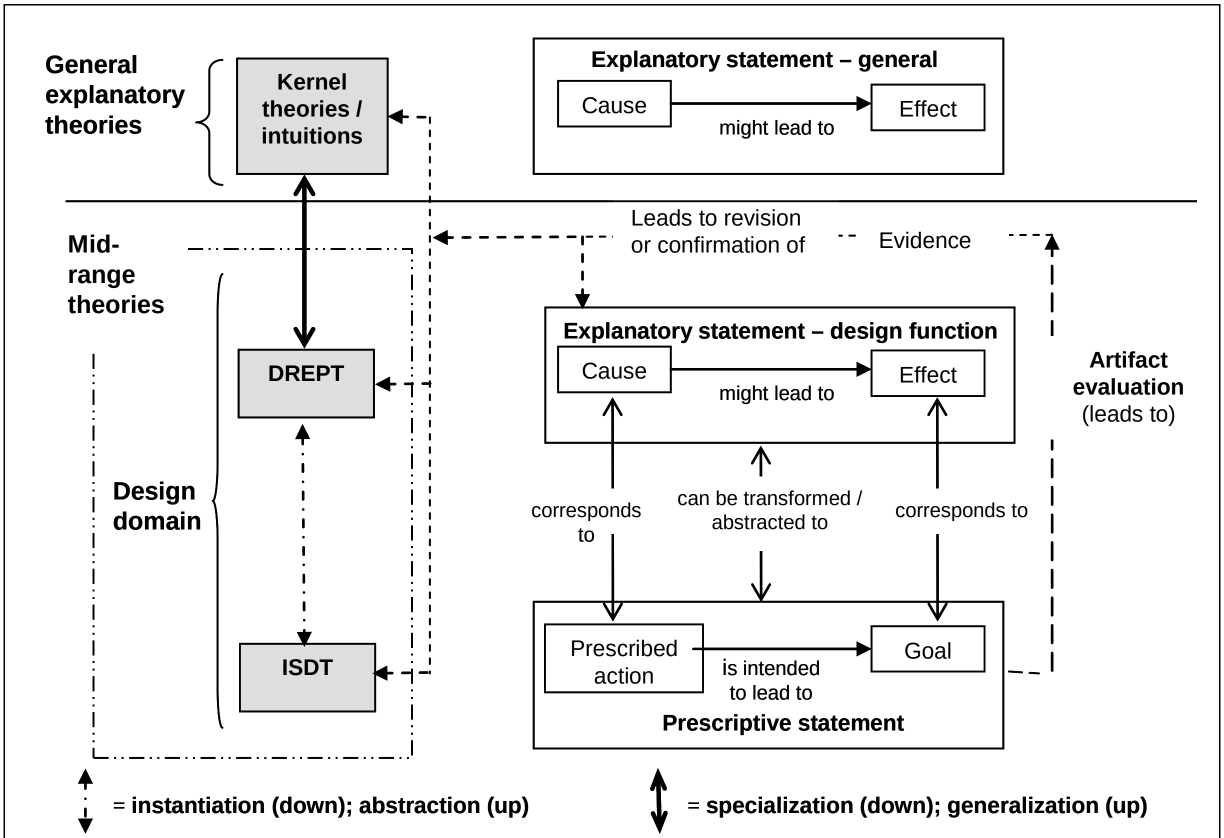
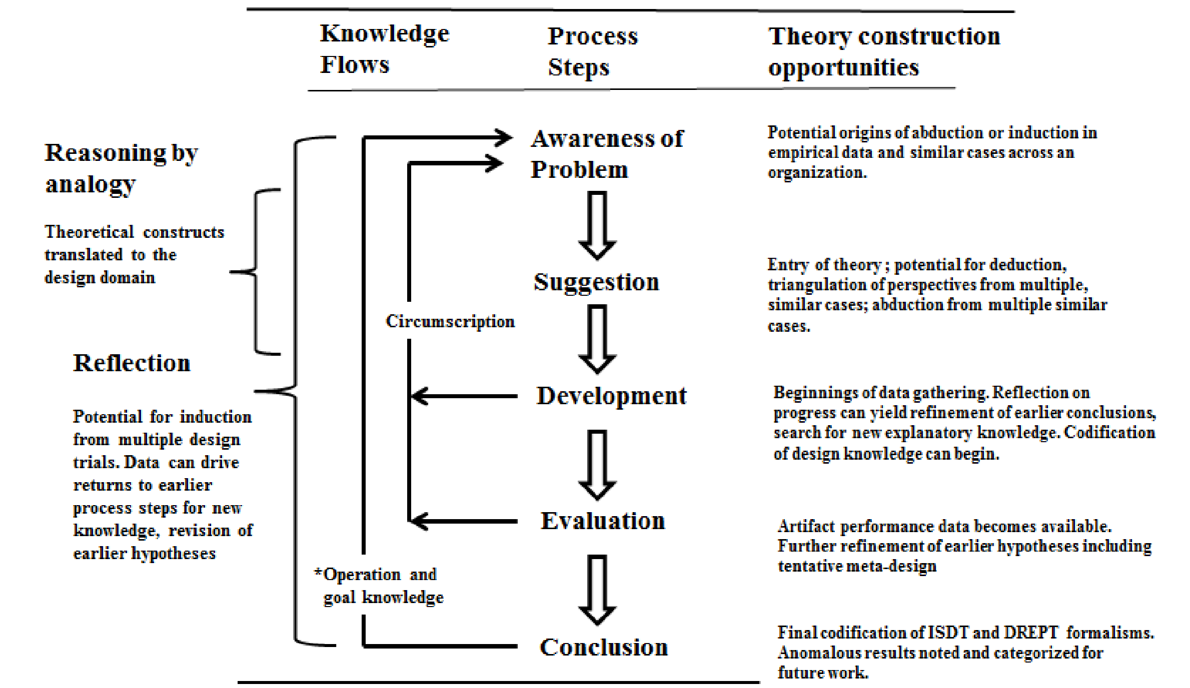


Figure 3. Relationships Between Kernel Theory, Mid-Range Theory, Design Theory, and DSRIS (modified from Goldkuhl, 2004)

We interpret Figure 3's "explanatory statement" heading 3 to include Gregor's (2006) theory types II, III, and IV: Explanation, prediction, and explanation and prediction, respectively. The heading "Prescriptive statement" corresponds to Gregor's type V theory for "design and action". The shaded boxes are our addition to relate epistemological statements to the DSRIS terminology we use throughout this paper. The dashed arrows also are our additions to illustrate relationships between knowledge levels and DSRIS activities.

Figure 4 illustrates the reasoning that takes place in an idealized design research cycle. New knowledge production is indicated in Figure 4 by the arrows labeled "circumscription" and "operation and goal knowledge". The circumscription process is especially important to understanding DSRIS because it generates understanding that could only be gained from the specific act of construction. Circumscription is a formal logical method (McCarthy, 1980) that assumes that every fragment of knowledge is valid only in certain situations, and validity can frequently not be predicted from theoretical considerations in advance. The knowledge has to be used – in this case, as part of a working design – in order to clarify the implications of the theory in a given circumstance. This is not due to a misunderstanding of the theory, but due to the necessarily incomplete nature of any knowledge base. The design process, when interrupted and forced back into an earlier phase in this way, contributes valuable constraint knowledge to the understanding of the always-incomplete-theories that abductively motivated the original design.



*Operational knowledge (principles) can be defined as “any technique or frame of reference about a class of artifacts or its characteristics that facilitates creation, manipulation and modification of artifactual forms” (Dasgupta, 1996; Purao, 2002).

Figure 4. Reasoning in the Design Research Cycle (extended from Vaishanvi & Kuechler, 2009, as Adapted From Takeda, Veerkamp, Tomiyama, & Yoshikawam, 1990)

Figure 3 is especially helpful in grounding levels of theory in DSRIS project activities or phases, which are illustrated in Figure 4. In a DSRIS project, the overarching context is one of a business problem situation (Hevner et al., 2004). The <goal> of the project (ISDT level in Figure 3) is typically the development of a technological solution to all or an aspect of the problem. The problem and potential solution are set out, at least in functional terms, in the awareness of problem phase (Figure 4). Following awareness of problem, possible solutions to the problem – ways of achieving the goal – are researched and preliminarily evaluated during a suggestion phase (Peffers et al., 2007; Vaishnavi & Kuechler, 2009). General explanatory statements of the form “<cause> might lead to <effect>” (see Figure 3) are derived from kernel theories or suggested by experience-guided intuition; the <cause> in the explanatory statement suggests, by some train of reasoning, a <prescribed action> that might have an ameliorating effect on the problem situation. The cognitive mechanism we propose is most used during the conceptual translation from the theoretical domains to the design domain (the solid arrow in Figure 3 labeled specialization/generalization) is analogical reasoning (Gentner, 1983; Keane, 1997); we discuss this further as a theory development technique in Appendix C. The same specialization arrow in Figure 3 marks the concretization[10] of dependent variables and independent variables from kernel theory to artifact features and effects in DREPT.

[10] As constructs are specialized, they are constrained by the context of the domain and become more concrete. For example, an explanatory kernel theory from psychology might contain the construct: “The number of visual field elements to which the subject can attend”. When moved into the domain of the design of an information presentation screen, the construct may become “the number of screen icons to which the subject can atten”.

In the development phase (Figure 4), DSRIS project activity now becomes more concrete and specific; reasoning has moved from a high-level solution search to a design problem: What artifact might produce the <prescribed action> by what means (what design features) and, thus help effect the <goal>? This reasoning is represented by the dashed arrow in the left pane of Figure 3 labeled instantiation/abstraction and by the two arrows from explanatory statements to prescriptive statements in the right pane. During an implementation phase of the project (Peffers et al., 2007; Vaishnavi & Kuechler, 2009), tentative solution artifacts are designed and constructed; this phase is frequently advised by another set of [design] kernel theories, which ground the implementation of similar artifacts. Validation of the artifact generates information that is used to assess the correctness of the entire reasoning /circumscription chain – the dashed lines and the heavy arrows of Figure 3 – completing a DSRIS suggestion-construction-evaluation cycle (Hevner et al., 2004; March & Smith, 1995; Nunamaker et al., 1991). A DSRIS project typically consists of many such cycles. Data on the effectiveness of the solution artifact – “evidence” in Figure 3 – may cause the theoretical statements on the left hand side of Figure 3 to be revised or even abandoned and replaced by a new derivation from a new kernel theory or theories.

The chain of reasoning between explanatory theory and the design domain, the mapping between kernel theories and design theories, between solution space (kernel theories) and attribute feature space (design – ISDT) is frequently not obvious; yet following the traditional method of DSRIS, it is never explicated or even consciously noted. With our additions to Figure 3, it is clear that this logical bridge between explanation and prescription must always exist and, if explicated, can be captured in DREPT.

9. Theory Construction in DSRIS: Two Published Examples

In Sections 8 and 9, we present a typological perspective and an epistemological perspective on our DSRIS theory-building framework. We first discuss the types of theory pertinent to DSRIS and the relationships between the dependent and independent variables of the different levels of theory. We then use an epistemological approach to explore the semantics of the different types of theory and related levels of theory to the information flows to and from different phases in the design research cycle. In the following discussion, we apply our framework for theory development to two published examples of DSRIS. We fully develop a DREPT for both papers to illustrate the use of the theory development framework and to demonstrate the potential value of this level of theory for DSRIS.

The DREPTs we propose are based on the constructs set out in the respective authors’ analyses of their kernel theories and the statements of their ISDTs. These DREPTs capture plausible chains of reasoning from the kernel constructs – the explanatory statements of Figure 3 – to the design theory injunctions – the prescriptive statements of Figure 3. An ISDT is explicitly developed in each of our published examples and, after developing the DREPT, we show how each ISDT constitutes a concretization of dependent and independent variables as predicted by our framework. Since DREPT is explanatory theory, it generates hypotheses that can be tested by constructing artifacts according to the hypotheses and then evaluating the artifacts. We propose that every DREPT include testable hypotheses to aid future researchers, just as testable propositions are included in the Walls et al. (1992, 2004) ISDT formalism (Table 3). We have derived several testable hypotheses for each of our examples.

The tabular approach illustrated in Table 3 makes the specialization of theory constructs obvious and is used to concretely illustrate both DREPT and ISDT development for our two published examples. Note that Table 3 combines analogical reasoning and deduction (See Appendix C).

Table 3. Logical Form and Semantics for Kernel to DREPT Mapping			
Non-IS Kernel construct / proposition	**Mapping**	**DREPT construct / proposition**	**Semantics**
X (construct)	➔	Y (construct)	Construct (or concept) X from outside IS maps (is analogous) to DREPT construct Y.
B (action)	➔	D (action)	Action B from a descriptive theory outside IS is analogous to IS artifact-achievable action D.
C (general effect)	➔	E (artifact induced effect)	An effect described in a theory from outside IS is analogous to the more restricted effect caused by the use of the designed artifact .
B acting on X causes C	➔	Do D to Y to get result E	Thus, since performing B on X causes general effect C, then an artifact performing activity D on Y will yield effect E.

9.1. Kasper (1996)

Our first DREPT "retrodiction" example is based on Kasper (1996), which was one of the first IS design science research efforts to explicitly develop an ISDT; the design theory specified design criteria for decision support systems (DSS) exhibiting improved calibration (roughly: the ratio of confidence in a decision to its correctness). Kasper does a very thorough job of setting forth the kernel theories from which his ISDT derives. The kernel theories derive from three streams, the first two from psychology and the third from behavioral decision making:

1. Mental representation (mental models)
2. Problem solving
3. Calibration in decision making.

Since no artifact is constructed and validated in the course of this work, there can be no demonstration of induction from artifact evaluation data for theory development. However, Kasper (1996) explicitly uses several of the methods we have proposed for theory development in Appendix C, and we have attempted a hermeneutic extension of the narrative ratiocination of the paper to a "likely" DREPT.

For both examples, our hermeneutic proceeded as follows:

- We carefully read the paper itself
- We carefully read the kernel theory papers
- We identified constructs and propositions in the kernel theories
- We identified constructs and proposition in the ISDT
- We attempted to enter into the author's logic as he described what to him are the most salient features of the ISDT and the kernel theories
- Using analogical reasoning, abduction, deduction, triangulation of perspectives, or some combination of these (see Appendix C), we set out probable mappings from kernel constructs and propositions to ISDT constructs and propositions
- We reconstructed the logic that justifies the mappings.

9.1.1. Kernel Theory Constructs and Propositions

From problem solving and behavioral decision making literature (constructs are bolded):

- As the proportion of **inference** [conscious, abstract reasoning] in one's **mental representation** of a problem increases, the likelihood of mis**calibration** increases (Waggenaar, 1988).

- The proportion of inference to **memory** [direct recall of information] used to formulate a mental representation is one determinant of **problem novelty**. The more novel the problem, the more inference is required (Kaufmann, 1985).

From problem solving and mental representation literature:

- The **locus of symbolic representation** of a problem shifts from linguistic to visual to exploratory as problem novelty increases (see the figures in Appendix B) (Kaufmann, 1985).

9.1.2. ISDT Constructs and Propositions

- A DSS exhibits design properties of **expressiveness**, **visibility**, **and inquirability** (Davis & Kottermann, 1994).

- Design method: "The locus of the DSS design process needed to produce a specific DSS whose users are perfectly calibrated varies with problem novelty from **expressiveness** to **visibility** to **inquirability**" (Kasper, 1996, p. 226).

Two different theories from psychology are used to give different perspectives on the construct of DSS calibration. Waggenaar (1988) proposes a relationship between abstraction in mental representation and miscalibration. Kaufmann (1985) proposes that the abstraction level of a mental representation of a problem increases with problem novelty. Kauffman's diagrammatic representation of the change in modes of representation with problem novelty is shown in Appendix B; Kasper's interpretation of this diagram in terms of DSS attributes is shown below Kauffmann's. A third perspective empirically investigates the effects of specific DSS design features (Davis & Kottermann, 1994). The result of this triangulation of perspectives (see Appendix C) on the construct of calibration is the ISDT for a DSS exhibiting improved calibration.

Note the very liberal use of analogical reasoning, the mechanism that proposes similarity between the constructs in different domains, in this case, between kernel theories and artifact design attributes. It is quite apparent (on reflection) that what Kasper (1996) has done is map expressiveness to linguistic mental attributes of a problem, visibility to visual mental attributes of a problem, and inquirability to what Kauffman (1985) in his kernel theory terms the exploratory aspect of a mental problem representation. However, it is misleading to construe the surface apparentness as obviousness. In point of fact, there is no obvious valid reason to suppose the ISDT concept of expressiveness – which is an aspect of a computer artifact interface – is related in any way to the construct linguistic representation from Kauffman's kernel theory – which is an aspect of an internal mental representation of a problem. The same is true for the other two mappings; they are hard-won insights on Kasper's part, highly unlikely without the serendipitous confluence of the three kernel theory papers used in the triangulation of perspectives.

To see the tenuousness of the analogy, readers are invited to scan Kauffman (1985) (one of the three kernel theory references for Kasper's (1996) paper) and try to imagine themselves making the linkage between the concepts in that paper and any aspect of DSS without first having seen the analogy in Kasper's paper. Note that Kauffman is technology neutral, and makes reference to no artifact whatsoever. In fact, the reasoning necessary to justify the mappings and to justify the manipulation of ISDT constructs toward the goal of improved calibration constitutes a sophisticated DREPT which, once explicitly set forth and validated, is valuable far beyond the DSS context. Table 4 illustrates the mappings of the DREPT, a theory of computer mediated problem representation effectiveness, their proposed (testable) justification, and a narrative statement of the theory.

Table 4. A Theory of Computer Mediated Problem Representation Effectiveness

Kernel construct / proposition		**IS mid-range construct / proposition**	**Semantics**
Linguistic representation	➔	Expressiveness	This mental problem representation aspect suggests an analogous aspect in a computer system interface.
Visual imagery	➔	Visibility	As above.
Exploratory reasoning	➔	Inquirability	As above.
Problem novelty	➔	Problem novelty	Problem novelty maintains a common meaning in both kernel theories and the ISDT.
The more novel the problem, the more abstract the mental representation.	➔	Matching mental representations with interface analogues (above) leads to better decisions.	A more verbally expressive interface matches (corresponds in some beneficial way) with the language component of a system user's mental problem representation; likewise, the visual aspects of an interface correspond with the visual imagery component of a mental problem representation. The level of dialectics (the amount of conscious thought required for response) of the interface corresponds with the degree of abstraction of the mental problem representation.
Narrative Statement			
From the kernel theory propositions above, we infer that the more novel the problem, the more the mental representation of the problem shifts from concrete – linguistic and visual representations, many drawn from memory – to abstract – reasoned relationships outside prior experience. The more exploratory reasoning (abstraction) figures in a problem representation, the greater the likelihood of miscalibration, and the greater the likelihood of ineffective decisions. Many computer systems have as their final goal or as important intermediate goals, assisting the user with a decision. System interfaces possess attributes of expressiveness, visibility, and inquirability. If the novelty of the decision situation is known, then altering the system interface attributes will allow the computer interface (display/interaction) representation of the problem to match the users' internal representation, and this will result in better decisions and more effective systems. Specifically, the interface should shift emphasis from expressiveness to visibility to inquirability as problem novelty increases.			

The italicized text in the narrative statement of the theory in Table 4 states the key assumptions of the theory. As stated, they lead easily to hypotheses testable through the construction and evaluation of artifacts that embody the propositions. We have diagrammed the construct mappings and the assumptions of the DREPT in a model that readily suggests empirical validation efforts (Figure 5 below). Two testable hypotheses taken directly from the model are:

1. When the problem represented in a decision support system is highly novel, decision effectiveness will be increased by increasing the DSS interface inquirability (as that term is defined above).

2. When the problem represented in a decision support system is well understood (low novelty), a simple, language-based interface is optimal for decision effectiveness.

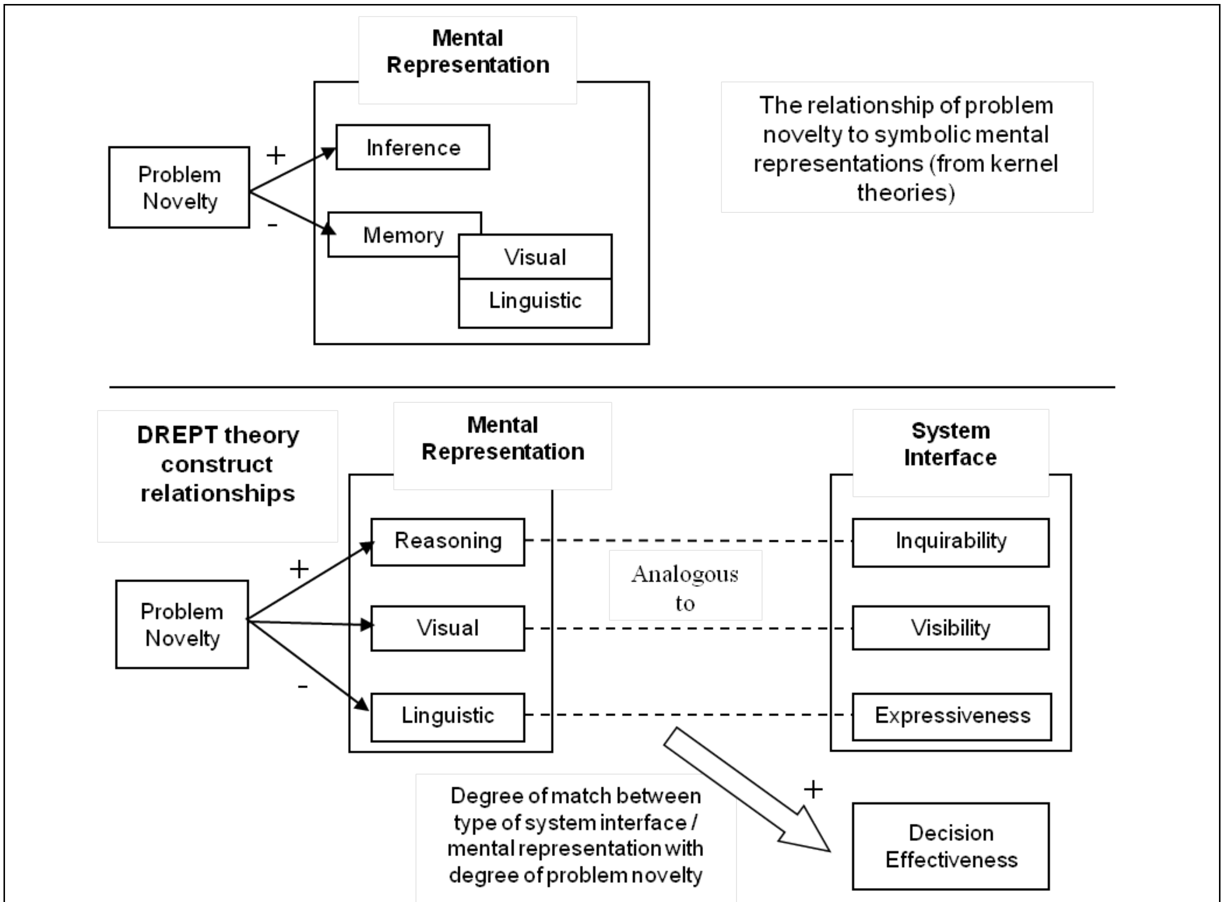


Figure 5. A Model of the Theory of Computer Mediated Problem Representation Effectiveness

Validating the DREPT would also, at one remove, provide validation for one of its kernel theories, Kauffman's (1985) theory of symbolic mental problem representation. Modifications to the DREPT, as would likely be necessary in the course of several design-build-evaluate cycles, would, depending on the nature and extent of the modifications, reflect back on and propose modifications to the kernel theory. This cycle of empirical reasoning is shown in Figure 3 as the dashed lines leading from prescription (artifact) to evidence (validation information) back to description (kernel theories). Kuechler and Vaishnavi (2008b) discuss the cycle in some length relative to another DSRIS project. We note that kernel theory validation of Kauffmann (1985) is a matter of considerable significance in this case (Kasper, 1996), since Kauffmann's theory was published with little, if any, empirical validation. The same situation is likely in any DSRIS effort where the kernel theories are taken from the most current literature of another field. Note also that the DREPT not only has value for researchers directly following in the area of DSS calibration but also has obvious value for any IT artifact during the use of which decisions are made on novel information; search engine interfaces are a good example of this type of artifact, as are spreadsheet add-on modules for contingent data analysis (what-iffing).

9.2. Arnott (2006)

The same DREPT extrapolation technique that we applied to Kasper (1996) can be applied to any published example of DSRIS. Our second example is Arnott (2006), a paper also chosen in part due to its use of kernel theories from psychology; our familiarity with the area greatly aids in hermeneutic interpretation. For this case the mapping from kernel theories to design theory is more obvious than that in Kasper. However, we feel useful and valuable knowledge gained in the development and evaluation of the final artifact remains tacit in Arnott as written. We use three of the theory-building techniques we have proposed in Appendix C to construct a broad DREPT with a wider range of applications that makes this knowledge explicit, demonstrating the generality of the techniques in capturing knowledge otherwise lost in a DSRIS project.

Arnott (2006), like Kasper (1996), is concerned with remedying shortcomings in decision support systems. Specifically, Arnott makes the case that development of DSS should – in fact, must – be evolutionary, yet there exists no methodology specifically for this task. The artifact produced by Arnott's DSRIS effort is an evolutionary DSS development methodology that focuses specifically on the types of bias that can occur in decision making and produces a DSS that minimizes those types of bias that might occur in the specific decision area for which the DSS is being produced.

Arnott (2006) explicitly uses a slightly modified version of the DSRIS development cycle shown in Figure 4, and it is convenient to discuss the paper's grounding literature with reference to that illustration. For the awareness of problem phase Arnott draws from IS development literature to show that DSS should be developed during the course of an evolutionary process and that the results of DSS usage have frequently been less beneficial than anticipated. During the suggestion phase of the DSRIS effort, Arnott turns to multiple areas outside IS for a better understanding of decision-making cognition. Psychology and cognitive science supply a taxonomy of biases – predispositions to deviation from rational decision making – that could be countered by a properly designed DSS. Behavioral decision making and management science literature suggest decision process models that can help to overcome different types of bias. For Arnott, as for Kasper (1996), triangulation of perspectives (see Appendix C) is used; multiple theoretical frameworks with emphases different from each other and from Arnott's emphasis are dissected for relevant foci and these are "reassembled" into a coherent whole focused on Arnott's design issues. We suggest triangulation of perspectives is inevitable whenever multiple kernel theories form the basis for the artifact design grounding.

During the development phase, Arnott designs an evolutionary DSS development methodology that focuses on identifying likely biases for the types of decisions the DSS will support, and incorporates debiasing techniques into the DSS design. This DSS development methodology is used in a single DSS development effort, and during the Evaluation phase, the effectiveness of the development effort is studied, guided by case analysis literature from management science (Yin, 1994).

Arnott determines the result of his design effort, the evolutionary, debiasing DSS development methodology, to be conditionally successful. We agree; in addition, however, Arnott's presentation of the grounding and results of his DSRIS project, subject to the techniques of triangulation of perspectives applied to his kernel theories combined with induction from his case observations can be used to construct a theory of the decision debiasing effects of participation in iterative system development. Induction from the data collected in multiple phases of the case observation strengthened and added additional richness to the theorizing process. The DREPT suggests both immediate follow-up studies in the area of DSS construction methods, and also more general empirical studies of IS construction processes as decision and problem reframing techniques (in addition, of course, to being ways of building a system). The kernel theory propositions and case observations that underlie the theory are as follows.

9.2.1. Kernel Theory Constructs and Propositions

From psychology and cognitive science (constructs are bolded):

- Humans are subject to **biases** in decision making. A number of biases have been investigated and grouped into taxonomies that suggest the types of biases that are most likely with different types of decisions (many surveyed in Fischoff, 1982).

From cognitive science and behavioral decision making (constructs are bolded):

- The **cognitive process** of coming to understand a decision – investigating the decision and its options – can significantly reframe the decision (**reframing**) (Keren, 1990).
- A **structure modifying task,** wherein the user can manipulate the internal structure of a [decision] task, is a known debiasing technique (Klayman & Brown, 1993).

9.2.2. Empirical Observations of the DSRIS Artifact in Operation (Constructs are Bolded)

- In the course of an extended, complex, **iterative DSS development** effort, the decision that is the focus of the DSS is significantly reframed.
- Both the primary **decision maker** and the **organizational personnel** who interact with the decision maker in the context of the decision participate in the insights from the problem reframing.
- The reframing results from **participation in the DSS development process** more than from any specific debiasing focus or DSS development method step.

While the risks involved in generalizing from a single case are well known, the observations in the case on which this theory is based were obtained over many months and were partially confirmed by having been observed during multiple iterations of the development methodology. We used induction to lift the level of abstraction for the theory from DSS development to IS system development, and our familiarity with most of Arnott's (2006) kernel theories, including those concerning IS development methods, leads us to feel this abstraction is justified. Table 5 details the constructs and propositions of the theory.

Table 5. A Theory of the Decision Debiasing Effects of IS Development Participation

Kernel construct / proposition		IS mid-range construct / proposition	Semantics
Bias	➔	Bias	Bias maintains a common meaning in both kernel theories and the ISDT – predisposition to deviations from rational decision behavior.
Structure modifying task	➔	IS (DSS) development process	An IS development process can be a [decision] structure modifying task.
Debiasing	➔	Reframing	Reframing can eliminate or minimize bias.
Decision maker	➔	IS system user/customer as decision maker	In the context of the theory, the decision maker is strongly concerned with the IS system.
Modifying the structure of the decision task can minimize or eliminate bias	➔	Participating in the development of the IS (broader than the DSS only context of the Arnott's project) can result in decision task structure modification and/or substantial reframing of the problem statement	When the participating domain personnel in IS development efforts are those who make decisions based on IS output, they can have their understanding of the contexts of the decisions, and of the entire IS, including inputs and outputs, reframed by their participation.
Narrative Statement			
From the kernel theory propositions above, we infer that processes that change the structure, both internal (mental) and external, of a decision task can decrease the bias associated with the decision. Information systems development, especially iterative development efforts that involve viewing the context, inputs, and products of a system from multiple perspectives, can result in changed perceptions of the decisions that provide input to the system or are made as a result of final or intermediate outputs of the system. Specifically, bias can be minimized for some of these decisions, resulting in better systems and the effective revision of the processes providing input to or requiring output from the systems.			

The original direction and final result of Arnott's (2006) research is certainly valuable in itself. However, a theory of the debiasing effects of participation in system construction, which we constructed from the published results of the paper with very little hermeneutic interpretation, is potentially even more valuable. It is at a significantly higher level than a design theory for an iterative, bias-focused DSS development methodology, the artifact developed in the paper. The DREPT also has a significant explanatory component, proposing as it does that many of the learning effects seen in systems development are due to the debiasing of long-standing, unchallenged organizational decisions. The theory is also applicable to iterative process reengineering made with or without IT support. We provide a model of the construct relationships from which DSRIS experiments to confirm or disconfirm the theory can be readily developed in Figure 6.

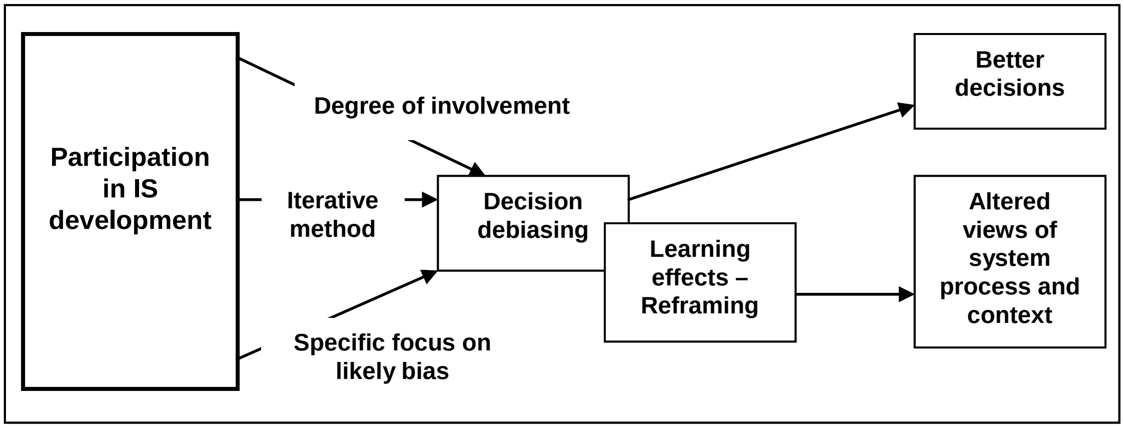


Figure 6: A Model of the Theory of the Decision Debiasing Effects of Participation in System Development

Two testable hypotheses taken directly from the model are:

1. A high degree of participation in an IS development effort will lead to more insightful views of the system process and context. Reframing of the originally stated problem situation for the system will mediate this effect.

2. When system development participants focus on possible biases from organizational assumptions to implicit system decisions, better development decisions will result. As for H1, reframing of the originally stated problem situation for the system will mediate this effect. (Thus, development methods that explicitly analyze the organizational assumptions that underlie the situation the system addresses will yield superior results.)

We suggest the theory can also be meaningfully investigated from a study of prior published cases of IS development that provide detail on the learning effects that occurred with respect to the system and its organizational context in the course of development.

10. Discussion and Conclusion

We wish to point out that the emphasis of the post-hoc theory derivations we provide above is on exercising the DSRIS theory development framework more than on the specific theoretical statements we derive. We realize that the nature of hermeneutic explication and the brief space we have for the explanation of our reasoning may make the specifics of our DREPT statements questionable to some. However, it should be noted that, through the use of our framework, we produce logically sound theoretical statements with clearly defined dependent and independent variables and obvious design implications. And this is precisely the sort of testable-through-artifact-construction theory we hoped our framework would enable. An example of use of an early version of the framework in an actual DSRIS project is developed in Kuechler and Vaishnavi (2008b). We present the kernel theory and DREPT propositions from that project in Appendix A.

In the course of developing a framework for theory development in DSRIS and illustrating its use, we necessarily touched on a wide variety of topics in limited depth. Working from a generalized notion of mid-range theory as applied to DSRIS, we expand on Gregor's (2006) typology of theory in DSRIS to include both theory for design and action (ISDT: Type V theory) and a design-relevant mid-range explanatory/predictive theory: DREPT. From that expansion, we propose a hierarchy of theory in DSRIS arranged according to level of abstraction of theoretical constructs. We further explicate the framework by an epistemological perspective that stresses the framework principle that transitioning between theory levels from kernel theory to artifact corresponds to increasing specialization (concretization) of independent and dependent variables. The framework by itself is useful for understanding design theories, their relations to kernel theories, and the roles each plays in the process of design. When combined with traditional theory development techniques – ways of thinking about design for design theory development (Appendix C) – the framework is useful in directing the construction of design theory as well.

We exercise our framework using two published examples of DSRIS. For both examples, we use our framework to formally explicate the ISDT that each paper developed. We additionally develop a DREPT for each to demonstrate the potential that that type of theory can have for DSRIS. As a mid-range theory, each DREPT is generalizable to the design of any artifact utilizing the phenomena of its grounding kernel theory(s) to achieve artifact effects.

In the first of the examples, Kasper (1996), the transition from kernel theories in psychology to an ISDT for a DSS exhibiting improved calibration seemed straightforward; however, closer examination showed that there was no logical reason or published empirical basis for the mapping from kernel theory constructs to ISDT constructs. We developed post-hoc a sophisticated and potentially very valuable DREPT to make that mapping logic explicit. We believe a broad gap between kernel theory constructs and design features is not unusual and that it increases with the amount of intuition required by the researcher to reason from kernel theory to ISDT.

In our second example, Arnott (2006), the gap from kernel theories to ISDT was substantially less; the mapping from kernel theory constructs to ISDT constructs was more transparent. However, by combining the techniques of induction and triangulation of perspectives, we were able to develop a DREPT that made explicit the substantial amount of information that was produced in Arnott's DSRIS project yet remained tacit. By reflecting on the theories that underlie the artifact and by using induction on the data produced by the artifact evaluation effort, we are able to propose a DREPT with very broad application – almost any IS development project – and correspondingly significant potential value.

As mentioned previously, this paper encompasses diverse material. We believe the breadth is required to ground the novel aspects of our framework within the context of theory development in DSRIS, which is relatively new itself. In much of the seminal DSRIS literature, theorizing beyond design models (ISDT) is conspicuously absent in descriptions of the outputs from design science research. Some of the reasons for this are historical and are described in Kuechler and Vaishnavi (2008a); significantly, many prominent design science researchers in IS were trained in computer science and engineering disciplines, and carried over a very pragmatic focus on the artifact-as-contribution. It is only in some of the newer publications on DSRIS (Gregor & Jones, 2007; Kuechler, Park, & Vaishnavi, 2009; Kuechler & Vaishnavi, 2008b; Venable, 2006) that explanatory/predictive theory has been mentioned as a possible contribution from a DSRIS project. We try to motivate the development of DREPT within DSRIS from two standpoints: (1) as a new but potentially valuable means of capturing design knowledge that would otherwise remain tacit in the design artifact and process and (2) as a formalism in our DSRIS theory development framework that helps to explain the nature of design theory and its relationship to both the artifact and kernel theories. William James once described philosophy as "an unusually stubborn attempt to think clearly and consistently" (Putnam, 1997). We hope to persuade the field that theory development in DSRIS be considered not as a complication or distraction, but rather as "an unusually stubborn attempt to capture knowledge clearly and consistently for the benefit of practice and cumulative research efforts".

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Appendices

Appendix A

Table A-1: Theoretical Constructs for Kernel and Mid-Range Theories (Kuechler & Vaishnavi, 2008b)

Construct	Definition
Mental model	The internal, cognitive model (in this case, of business processes) that contains the information about the model elements and their relationships
Modes of cognition	Modes of perceiving information that determine the types of information most readily acquired and the strength of relationships between information elements as mental models are formed
Surface understanding (of processes)	Understanding of the "mechanics" of process elements – flows, actors, and decisions at an algorithmic level – excluding domain or context information
Deep understanding (of processes)	Surface understanding combined with knowledge of the context in which the process operates and the interactions, actual and potential, between the process and its environment
Soft context information	Organizational, cultural or political information about the actors or environment of a process that is difficult to capture in conventional process notations but that is frequently critical to the success of the process. In a medical informatics context, for example, the aversion of many older MDs to information technology is one example of soft context.
Narrative (sometimes termed *text*)	Information in language form
Micro-rationales	Small, concise narrative segments relating process details or context not found in diagrammatic representations, usually woven into a coherent "story" about the process
Salience	In this context, the term denotes the degree of attention and significance given to different information elements of a conceptual model.

Kernel Theory Propositions (Kuechler & Vaishnavi, 2008b)

From the modal cognition literature:

- The cognitive model formed from information about a situation can be made more receptive to social or "soft" information by varying the mode of information presentation from abstract-propositional (numeric) to narrative (textual). (Note that a proposition of exactly this form can likely not be found in the literature. We have presented our interpretation, which at this point is quite informed. We have taken no liberties with matters of fact, but have "repackaged" conclusions from the kernel literature to concisely state what was of interest to us. The restatement also makes it easier to follow our development from one theory level to the next.)

From the multi-media comprehension literature:

- Richer cognitive models of physical processes that demonstrate greater transfer learning (across domains) result more from mixed-media presentations of the processes (i.e., text + illustrations) than from text or illustrations alone.

DREPT Propositions (Kuechler & Vaishnavi, 2008b) (A Theory of Grammatical Element Salience in Conceptual Modeling (GESCM))

1. In systems design, a conceptual model can be used to concisely represent one or more important aspects of the system.

2. A system always operates in a context. Usually the grammar(s) for the conceptual model(s) of the system are optimized for the representation of a narrow range of system constructs. Specifically, these grammars are not well suited to representing organizational context information, especially when they are graphical in form.

3. Organizational context information can be expressed in narrative (language) form.

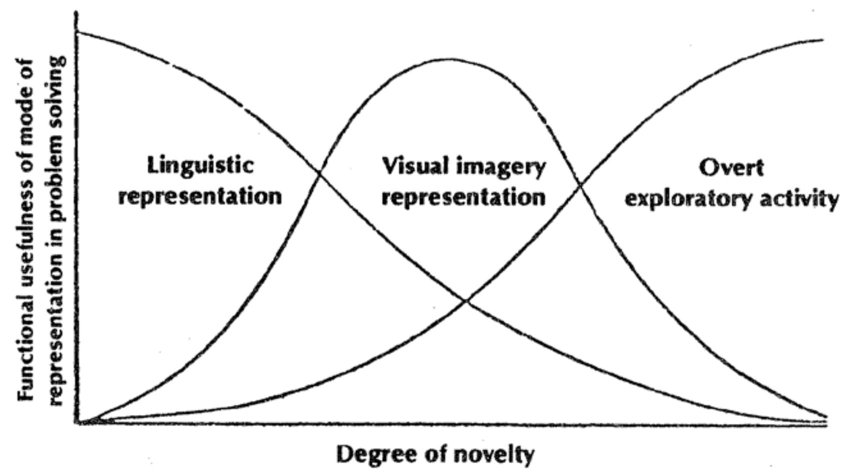
4. Virtually all business systems are artificial – they are designed, and there are reasons called design rationale that describe why they are as they are. Design rationale also can be expressed in narrative form.

5. When conventional (narrowly focused) conceptual models for processes are linked in a designer’s mental model to expressions of critical organizational context and design rationale, better design decisions are achievable.

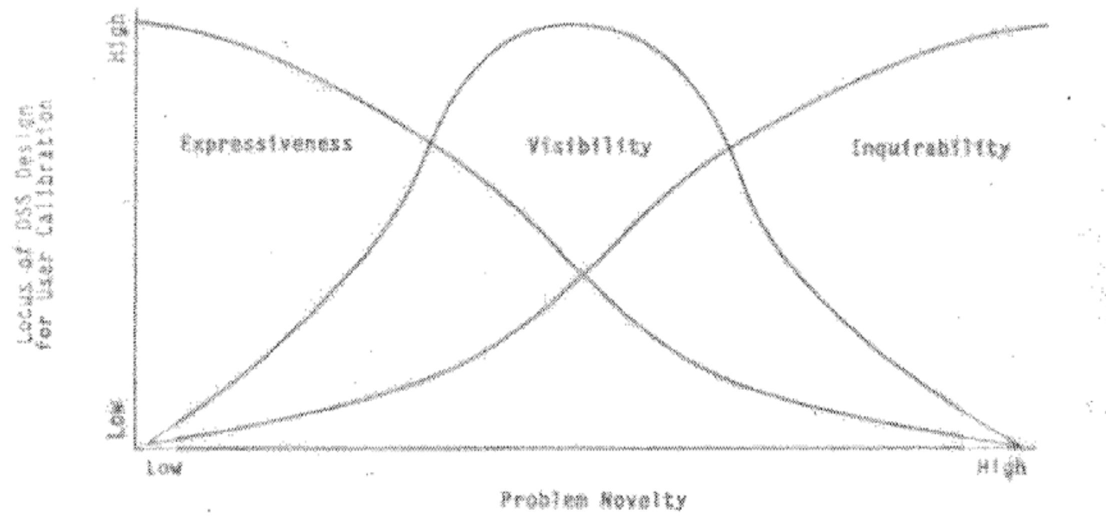
6. Computer-based conceptual model design and display artifacts can be built that force attentional links between conventional, conceptual model element displays and narrative information displays of organizational context and design rationale so as to facilitate the construction in the user of the artifact of mental models that link context information with the information captured by the conventional conceptual model.

7. The strongest and most useful overall mental model (conventional conceptual model and narrative components) will be produced when the narrative components are woven into a coherent (by basic literary standards) story rather than presented as separate, intelligible but logically unconnected text components. (This is one of the distinguishing features between a dual grammar conceptual model and a simple annotated conceptual model graphic display.)

Appendix B



Appendix B-1: Kauffman's Diagrammatic Representation of the Change in Modes of Mental Representation with Problem Novelty (Kauffman, 1985)



Appendix B-2: Kasper's (1996) Interpretation of Kauffmann's (1985) Diagram in Terms of DSS Attributes

Appendix C

This appendix presents some of the techniques of theory development we feel are most applicable to design theory construction. We cannot hope to do justice to this huge subject in an appendix to a paper; instead we briefly describe the techniques we have used in past DSRIS projects and that we have used in the examples in the main paper.

Table C-1 provides an overview of "ways of thinking about design" for design theory development; for each, we provide the name, a brief description of the technique, and references to more extensive information about the technique. We have termed these techniques "ways of thinking about design" that are useful for theory development rather than "rules of logical derivation" because design, both its practice and, necessarily, in theorizing about it, are resistant to and in some ways antithetical to the methods of traditional single valued Aristotelian logic. In fact, some of the techniques traditionally used and even promoted in design in all fields are logical fallacies when dissected by the axioms of first order predicate logic[11]. The methods and techniques are used (or, logicians might say, misused) because they work; by thinking about design and design knowledge (design theory) in these ways, designers for centuries have achieved useful, effective designs and have captured design knowledge in ways that can be effectively transmitted between designers and across generations (Latour, 1987; Feyerabend, 1993).

Appendix C-1: "Ways of Thinking about Design" for Design Theory Development

Technique	Description	References
Deduction	Allows deriving *b* from *a* only where *b* is a formal consequence of *a*. In other words, deduction is the process of deriving the consequences of what is assumed. Given the truth of the assumptions, a valid deduction guarantees the truth of the conclusion.	Craig, 2000; "Abductive Reasoning", 2010
Induction	Allows inferring *b* from *a*, where *b* does not follow necessarily from *a*. *a* might give us very good reason to accept *b*, but it does not ensure that *b*.	Craig, 2000; "Abductive Reasoning", 2010
Abduction	Allows inferring *a* as an explanation of *b*. Because of this, abduction allows the precondition *a* to be inferred from the consequence *b*. In other words *b* exists and can be observed; *a* (or *a1*+ *a2*+ …) is the most parsimonious and, therefore, most likely explanation of *b*.	Craig, 2000; "Abductive Reasoning", 2010
Triangulation of Perspectives	Creation of a novel viewpoint on a problem by extracting individual "element foci" from multiple solution approaches to similar problems and combining these into a coherent viewpoint	Pedersen et al., 2002
Circumscription	A rule of conjecture that allows "jumping to certain conclusions". Semi-formally: "The objects that can be shown to have a certain property P by reasoning from certain facts A are [considered for a given train of reasoning to be] all the objects that satisfy P" (McCarthy, 1980). Without circumscription, reasoning about the real world encounters the "qualification problem", whereby an intractable number of possibilities need be considered before making a logically defensible decision.	McCarthy, 1980
Analogical reasoning	Analogical reasoning is a mode of cognition in which the similarities between new and understood concepts are compared and the comparison used to gain understanding of the new concept. Analogical reasoning is a form of inductive reasoning in that it attempts to provide understanding of what is likely to be true, rather than a deductive proof of truth (or fact).	Gentner, 1983; Keane, 1997
Reflection	"The action or process of thinking carefully or deeply about a particular subject" (Oxford English Dictionary online, 2010). "Reflection on a design process is thus defined as a combination of reflection on the perceived design situation and reflection on the remembered design activities" (Reymen et al., 2006).	Reymen et al., 2006; Schon, 1983

[11] Abduction, for example, is equivalent to the logical fallacy of affirming the consequent.

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