

## POSITIONING AND PRESENTING DESIGN SCIENCE RESEARCH FOR MAXIMUM IMPACT<sup>1</sup>

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*Design science research (DSR) has staked its rightful ground as an important and legitimate Information Systems (IS) research paradigm. We contend that DSR has yet to attain its full potential impact on the development and use of information systems due to gaps in the understanding and application of DSR concepts and methods. This essay aims to help researchers (1) appreciate the levels of artifact abstractions that may be DSR contributions, (2) identify appropriate ways of consuming and producing knowledge when they are preparing journal articles or other scholarly works, (3) understand and position the knowledge contributions of their research projects, and (4) structure a DSR article so that it emphasizes significant contributions to the knowledge base. Our focal contribution is the DSR knowledge contribution framework with two dimensions based on the existing state of knowledge in both the problem and solution domains for the research opportunity under study. In addition, we propose a DSR communication schema with similarities to more conventional publication patterns, but which substitutes the description of the DSR artifact in place of a traditional results section. We evaluate the DSR contribution framework and the DSR communication schema via examinations of DSR exemplar publications.*

**Keywords:** Design science research (DSR), knowledge, design artifact, knowledge contribution framework, publication schema, information systems, computer science discipline, engineering discipline, DSR theory

*It is clear from the preceding that every "art" [technique] has its speculative and its practical side. Its speculation is the theoretical knowledge of the principles of the technique; its practice is but the habitual and instinctive application of these principles. It is difficult if not impossible to make much progress in the application without theory; conversely, it is difficult to understand the theory without knowledge of the technique.*

Diderot, "Arts" in *Encyclopédie* (1751-1765) (quoted in Mokyr 2002)

### Introduction

Design science research (DSR) has been an important

paradigm of Information Systems (IS) research since the inception of the field, and its general acceptance as a legitimate approach to IS research is increasing (Hevner and Chatterjee 2010; Kuechler and Vaishnavi 2008a). In IS, DSR involves the construction of a wide range of *socio-technical* artifacts such as decision support systems, modeling tools, governance strategies, methods for IS evaluation, and IS change interventions.

<sup>1</sup>Detmar W. Straub was the accepting senior editor for this paper.

The appendices for this paper are located in the "Online Supplements" section of the *MIS Quarterly*'s website (<http://www.misq.org>).

We contend that ongoing confusion and misunderstandings of DSR's central ideas and goals are hindering DSR from having a more striking influence on the IS field. A key problem that underlies this confusion is less than full understanding of how DSR relates to human knowledge. The appropriate and effective consumption and production of knowledge are related issues that researchers should consider foremost throughout the research process—from initial problem selection, to the use of sound research methods, to reflection, and to communication of research results in journal and conference articles. However, this issue becomes paramount in reflection and communication, and for this reason we focus on these activities in this essay.

The essay aims to help researchers (1) appreciate the levels of artifact abstraction that may be DSR contributions, (2) understand knowledge roles in DSR and so identify appropriate ways of consuming and producing knowledge when they are preparing journal articles or other scholarly works, (3) understand and position the knowledge contributions of their research projects, and (4) structure a DSR article so that significant contributions to the knowledge base are clear and present. In addition to being of interest to authors, the essay should engage editors and reviewers who seek guidance on what to expect from knowledge contributions in DSR.

Contributing to knowledge is seen as the foremost criterion for the publication of research (e.g., Straub et al. 1994). Consistent with this point of view, the mathematician G. H. Hardy is credited with the concise depiction of three important questions that are asked of a potential research contribution: Is it true? Is it new? Is it interesting? (Wilson 2002, p. 168). The last question is perhaps the most important. If it is answered in the negative, then there is no need to consider the first two questions. Wilson (2002, p. 169) recognizes the primacy of interesting contributions to knowledge and their clear communication in the first four key questions that he asks should be addressed by reviewers for journals:

1. Are the problems discussed in the paper of substantial interest? Would solutions of these problems materially advance knowledge of theory, methods or applications?
2. Does the author either solve these problems or else make contributions toward a solution that improves substantially upon previous work?
3. Are the methods of solution new? Can the proposed solution methods be used to solve other problems of interest?
4. Does the exposition of the paper help to clarify our understanding of this area of research or application? Does the paper hold our interest and make us want to give the paper the careful

reading that we give to important papers in our area of specialization?

The current essay aims to satisfy these questions for a DSR publication. Experience shows that many authors, reviewers, and editors struggle to present and interpret DSR work well with a clear understanding of knowledge contributions. The difficulties here likely arise from a combination of factors, which include the relative youth of the information technology disciplines, and the comparatively recent recognition of DSR as a distinct, yet legitimate, research paradigm.<sup>2</sup> Design science research has been practiced for some time in the engineering and IS disciplines, although under a variety of labels. Simon (1996) provided the seminal work on the “sciences of the artificial.” Relevant work in information systems has been referred to as “systemeering” (Iivari 1983), a “constructive” approach (Iivari 2007), and “systems development” or an “engineering approach” (Nunamaker et al. 1990-91). Yet mainstream recognition of DSR in information systems is acknowledged to have occurred with the 2004 Hevner et al. publication in *MIS Quarterly* (see Kuechler and Vaishnavi 2008a).

Even within the design science paradigm, some differences of opinion have emerged. One case of this is the bifurcation into a design-theory camp (Gregor and Jones 2007; Markus et al. 2002; Walls et al. 1992, 2004) and a pragmatic-design camp (Hevner et al. 2004; March and Smith 1995; Nunamaker et al. 1990-91), with the two camps placing comparatively more emphasis on design theory or artifacts respectively as research contributions. One aim of the current paper is to harmonize what we see as complementary rather than opposing perspectives, a repositioning that can enhance the conduct and reach of rigorous and impactful DSR.

The guidance we provide below for DSR positioning and publishing could mean that important and relevant work will reach a wider audience, dissemination of which contributes to both research and professional practice. This essay also provides theoretical significance in the philosophy of technology because there are still unanswered questions about how, and to what extent, DSR contributes to knowledge and generalized theory (Gregor 2006; Gregor and Jones 2007; Hevner et al. 2004; Kuechler and Vaishnavi 2012). Thus, we clarify issues concerning the role of theory and how partial or incomplete attempts at theorizing via artifact development can contribute to evolving theory.

<sup>2</sup>This is true especially when the IT disciplines are compared to the natural sciences, which grew to maturity during the 18<sup>th</sup> century Enlightenment, and to the social sciences, which began their rapid growth in the Victorian period. See Simon (1996).

The scope of the essay should be noted. A significant DSR program typically encompasses many researchers over several years with any number of intermediate research results during its evolution. For the purposes of this essay we primarily target the publication of single research articles and when the word *project* is used it refers to a portion of a larger program of research that is presented in one article. The importance of overall research programs that encompass many smaller projects is acknowledged in our recognition that single articles and projects can be interim attempts at theorizing but still be of value (see Weick 1995).

While this essay is primarily aimed at DSR in information systems, it has clear implications for other fields engaged in DSR, particularly in associated areas concerned with information technology (such as the Computer Science and Engineering disciplines). Information Systems specifically is seen as a discipline that concerns the use of information technology-related artifacts in human-machine systems (see Lee 2001, p. iii). We assert that the ideas and discussions contained here apply to a broad range of IT-related fields.

The essay proceeds as follows. The following section provides background from the extant literature for the main themes of our study. Here we address design theorizing and the definition and role of the IT artifact as a basis for appreciating levels of artifact abstractions that may be DSR contributions. The following three sections deal with the main themes of the essay: the roles of descriptive and prescriptive knowledge in relation to the economics of knowledge, the *DSR contribution framework*, and the *DSR communication schema*. We conclude by discussing the impact of these ideas on future DSR projects.

## Background

We first clarify important concepts and issues that recur throughout the essay. We then outline some of the prior literature that concerns the main themes. The references to prior literature are indicative rather than descriptive as there is a large body of work surrounding each theme.

### The Development of Design Theory

In discussing contributions to knowledge, we should consider the vexed questions of what is meant by theory, whether design knowledge can be a legitimate theoretical contribution, and, further, what role an artifact plays in design-science theorizing. A key theme of this essay is “contributions to

knowledge,” and we argue that the development of “strong” theory is only *one form* that a DSR contribution can take. We are of the view, as expressed in other branches of science, that contributions to knowledge could be partial theory, incomplete theory, or even some particularly interesting and perhaps surprising empirical generalization in the form of a new design artifact (see Merton 1968; Sutton and Staw 1995). To explain the preceding statement in more detail, we consider the nature of different forms of knowledge. One form of knowledge—theory—is seen as an abstract entity, an intermeshed set of statements about relationships among constructs that aims to describe, explain, enhance understanding of, and, in some cases, predict the future (Gregor 2006). The type of theory that formalizes knowledge in DSR is termed *design theory*, the fifth of the five types of theory in Gregor’s taxonomy. This type of theory gives prescriptions for design and action: it says how to do something. We consider design theory to be prescriptive knowledge as opposed to descriptive knowledge, which encompasses the other types of theory in the Gregor taxonomy (see Appendix A for a fuller discussion on design theory).

There are many steps, however, on the road to theory development. Exhibit 1, discussed in more detail later, demonstrates one process of maturation in a body of knowledge and theory development, beginning with the development of a novel artifact. Knowledge then becomes more abstract and more general, and the web of knowledge becomes more comprehensive with clearer delimitation of boundaries. Special conditions that might need variation in the theory are discovered. Pushing the knowledge beyond prior domain constraints and into new fields means that the boundaries of a theory receive more testing and more support. These advances mean greater understanding of when a theory works and why, and more evidence for a theory as a whole. Thus, the field (both problem and solution domains) is considered more mature.

In Merton’s terms (1968, p. 39), design theories are special theories or

theories of the middle range: 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 that will explain all the observed uniformities of social behavior, social organization, and social change.

All-encompassing theories are termed *grand theories*. It is not clear whether we have any grand theories in IS/IT design science, or even whether they would be particularly useful if

## Exhibit 1. Illustration of DSR Theory Development and Knowledge Contributions

A seminal paper in the field of knowledge discovery is that of Agrawal, Imielinski and Swami (1993), "Mining Association Rules between Sets of Items in Large Databases," which shows how significant relationships (association rules) can be extracted or "mined" from a large database so as to assist with human decision making. The design knowledge presented includes the description of the **method** for extracting the association rules, including the novel **constructs** of a *confidence level* (what percentage of transactions containing one part of the rule also contain the other part) and *rule support* (the percentage of transactions in the database satisfying the rule). Pseudocode for the algorithm involved in the method is also provided (**design principles**). This algorithm is converted to operational software in order to test the method on a large, real-life database. This operational software is an **instantiated artifact**.

This design knowledge satisfies many of the criteria for partial, nascent theory. There is a logically consistent set of statements. Constructs and statements are clearly defined with knowledge descriptions at an abstract level. The method, constructs, and algorithm are described in abstract terms without having recourse to the specific software language implementation. The paper implicitly contains **technological rules**: for example, "To find significant relationships in a large database, use the mining algorithm." These rules can be converted to an **empirical generalization** such as "Application of the mining algorithm leads to identification of all significant relationships," a statement that can be tested.

The design knowledge in this seminal paper, however, had not yet evolved to the stage where it could be termed **design theory**. There was no explanation of why the method works as it did, or a good account of the specific conditions under which it held. It was not yet known exactly what were the adequate confidence levels or degrees of rule support for effective decision making with databases of various sizes and types. Further, the knowledge had undergone only limited testing. Still, the paper proved to be enormously influential for subsequent work in knowledge discovery (with close to 12,000 cites in Google Scholar as of October 2012).

As knowledge of data mining through association rules developed, the more mature body of knowledge came to be termed **theory** (e.g., see Williams and Simoff 2006). Better algorithms were developed and tested, additional knowledge of constraints on the "interestingness" of relationships from the user point of view was developed, and the use of the method was extended to areas such as web usage mining, business intelligence, and security breach detection.

they did exist. Merton's view was that in an applied field (such as sociology or IS/IT), there should be a focus, but not an exclusive focus, on theories of the middle range (pp. 50-51) (see also Cook and Campbell 1979).

Apart from questions concerning design theory in general, the role of *kernel theories* is also an issue relevant to DSR. The term kernel theory was originally defined in Walls et al.'s (1992, p. 41) seminal work to refer to "theories from natural science, social sciences and mathematics" that are encompassed in design theory. The meaning of the term has since blurred and, in many instances in the field of IS, it is used synonymously with the term *reference theory* to mean theory that arises in disciplines outside of IS.

In the present paper, kernel theory refers to any descriptive theory that informs artifact construction, as in Gregor and Jones (2007). A mature body of design knowledge should include kernel theory because such theory explains, at least in part, why the design works. We employ the term *justificatory knowledge* to be nearly synonymous with kernel theory. It

needs to be noted, though, that justificatory knowledge has a slightly broader meaning and here it is taken to include any knowledge that informs design research, including informal knowledge from the field and the experience of practitioners (Gregor and Jones 2007). Note that descriptive theory may be tested and refined during the creation of a design theory (Kuechler and Vaishnavi 2008b) but this issue is beyond the scope of this essay.

### The Artifact as DSR Knowledge

Having considered the role of design theory and its development, we turn more specifically to the role of the IT artifact.<sup>3</sup> It is important to further clarify the relationship between the nature of the artifact/object/problem space

<sup>3</sup>We clarified in the introduction that, in IS, our main interest is in socio-technical artifacts. However, the terms artifact, IS/IT artifact, and IT artifact are used more or less synonymously throughout the essay.

studied in DSR as separate from the contributions made by a DSR study. Confusion arises because the abstract knowledge contributions that are created in DSR (e.g., design theory) can also be treated as a type of artifact. In general, the term *artifact* is used in this paper to refer to a thing that has, or can be transformed into, a material existence as an artificially made object (e.g., model, instantiation) or process (e.g., method, software) (Goldkuhl 2002, p. 5). Many IT artifacts have some degree of abstraction but can be readily converted to a material existence; for example, an algorithm converted to operational software.

In contrast, a theory is more abstract, has a nonmaterial existence, and contains knowledge additional to the description of a materially existing artifact. There is a need to address the perception that the so-called DSR camps require different types of research contributions to be “true” DSR: that is, the construct, model, method, and/or instantiation of Hevner et al. or the design theory of Gregor and Jones. These apparent inconsistencies can be reconciled by recognizing the importance of **both** the contributions made in the form of viable artifacts and the contributions at more abstract levels.

We have seen how the construction of an artifact and its description in terms of design principles and technological rules are steps in the process of developing more comprehensive bodies of knowledge or design theories. The illustration of the association rules method (Exhibit 1) demonstrates how the initial set of design artifacts was a first step in the development of data mining theory. In Exhibit 1, the physical, instantiated artifact was the operational software used in tests with a supermarket database. If this were the only artifact offered, however, this paper may not have been published. This type of artifact is similar to a case study description where there is no abstraction or extraction of underlying principles and where the possibilities of generalizing to other situations are slim. The research contribution offered by Agrawal et al. (1993), therefore, includes other, more abstract artifacts. These artifacts are the overall method description, the constructs (confidence level and rule support), the design principles (the necessary steps in the algorithm in pseudocode), and the implicit technological rules. Offering these artifacts at an abstract level means that they can be operationalized in a number of other unstudied contexts, thus greatly increasing the external validity of the research. These artifacts are not yet, however, at the level of a comprehensive theory.

Table 1 shows how the ideas developed above can be applied. This table builds on a framework introduced by Purao (2002) to show how to distinguish different DSR “outputs” as research deliverables, with three maturity levels of DSR arti-

fact types and examples at each level. A specific DSR research project can produce artifacts on one or more of these levels ranging from specific instantiations at Level 1 in the form of products and processes, to more general (i.e., abstract) contributions at Level 2 in the form of nascent design theory (e.g., constructs, design principles, models, methods, technological rules), to well-developed design theories about the phenomena under study at Level 3.<sup>4</sup>

There are, however, some important differences between the framework in Table 1 and the Purao framework. In Table 1, we differentiate the levels of knowledge contribution not only in terms of a transition from less abstract to more abstract, but also in terms of the knowledge’s maturity level: How far has the knowledge advanced in terms of the characteristics of a well-developed body of knowledge (Nagel 1979)? These distinctions are the foundation of the knowledge contribution framework that we present later in the essay.

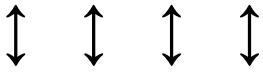
### ***Demonstrating a Contribution to Knowledge***

Having discussed the forms that a contribution can take in DSR, we turn next to the question of how a contribution is signaled to the scientific community. The type of knowledge contribution that is expected in a specific research project can vary with the community and publication outlet. For example, journals such as *MIS Quarterly* expect a clear theoretical contribution from research articles and only in research notes can there be simple empirical findings or a detailed description of an artifact. In the social sciences, there is considerable discussion about what it means to make a contribution to theory and how to signal a contribution in a journal article. Weick (1995), for example, acknowledges the importance of strong theory and describes how interim attempts at theorizing can be valuable in a process of theorizing. Indications of how contributions can be signaled are also provided in advice to authors from journal editors (e.g., Feldman 2004; Straub 2009).

In the IS literature to date, however, there is limited advice on how to signal and assess the degree of contribution in a DSR project. In Hevner et al. (p. 81) we find “design-science research addresses important unsolved problems in unique or innovative ways or solved problems in more effective or effi-

<sup>4</sup>Note that we would still include the **artifact** or situated implementation (Level 1) as a knowledge contribution, even in the absence of abstraction or theorizing about its design principles or architecture because the artifact can be a research contribution in itself. Demonstration of a novel artifact can be a research contribution that embodies design ideas and theories yet to be articulated, formalized, and fully understood.

**Table 1. Design Science Research Contribution Types**

	Contribution Types	Example Artifacts
More abstract, complete, and mature knowledge    More specific, limited, and less mature knowledge	Level 3. Well-developed design theory about embedded phenomena	Design theories (mid-range and grand theories)
	Level 2. Nascent design theory—knowledge as operational principles/architecture	Constructs, methods, models, design principles, technological rules.
	Level 1. Situated implementation of artifact	Instantiations (software products or implemented processes)

cient ways.” Davis (2005) presents some general concepts that define a contribution in a Ph.D. thesis, points which are also relevant to research articles. One form of contribution is whether the thesis

develops and demonstrates new or improved design of a conceptual or physical artifact. This is often termed “design science.” The contribution may be demonstrated by reasoning, proof of concept, proof of value added, or proof of acceptance and use (p. 18).

Davis goes on to show some conditions under which development work would not be considered a contribution, for example, when a project has been completed in industry (although the project may have required a significant effort and the results were useful). However, industry results are typically not suitable for a research thesis or paper because “they do not make a contribution to knowledge other than actually doing something that everyone knows can be done and at least conceptually how to do it” (p. 18).

We conclude that the field has not reached an understanding as to what defines a clear knowledge contribution from a DSR project. This shortcoming has limited the acceptance and impact of DSR in the IS community. Thus, the primary goal of this essay is to provide usable guidance on how to understand, position, and present DSR knowledge contributions.

In addition to a knowledge contribution, effective DSR should make clear contributions to the real-world application environment from which the research problem or opportunity is drawn (Hevner et al. 2004). While our emphasis is on the clarification of the role of scholarly knowledge contributions in DSR, we would be remiss not to mention the important contributions that DSR projects make to praxis. The relevance of research results to applications in business has been highlighted as a key distinguishing feature of DSR in IS research commentaries (e.g., Straub and Ang 2011).

Recent debates in the IS community have centered on the importance of contributing to practice via IS research. The German *Wirtschaftsinformatik* community has published a memorandum calling for greater recognition of design-oriented IS research and has drawn attention to the close working relationship of industry and academia in Europe (Österle et al. 2011). In a similar vein, Gill and Bhattacharjee (2009) decry the lack of practical “informing” provided to clients by most IS research. Responses to these concerns highlight the openness of the IS community and its research journals to DSR projects and emphasize the need to publish both theory and practice contributions (Baskerville et al. 2011; Myers and Baskerville 2009).

## Research Approach

In essence, the method employed in developing this essay is itself a DSR approach. Methods for DSR are available in a number of forms (see Hevner and Chatterjee 2010; Vaishnavi and Kuechler 2008). Our method parallels that described by Peffers et al. (2008) and includes the following steps: (1) identify problem; (2) define solution objectives; (3) design and development; (4) demonstration; (5) evaluation; and (6) communication. The Peffers et al. research process offers a useful synthesized general model, building on other approaches. Further, we find this model to be compatible with our underlying ontological perspective, which follows that of Popper (1978) and Habermas (1984) (see also Gregor and Jones 2007; Iivari 2007). The Popperian/Habermas high-level ontology perspective is a pluralist form of realism in which three separate domains are recognized: the objective world of material things (World 1), the subjective world of mental states (World 2), and an objectively existing but abstract world of human-made entities—language, theories, models, constructs and so on (World 3). This ontological perspective allows distinctions to be drawn between instantiations of artifacts (World 1) and abstract knowledge (World 3) (as in Table 1) and also the subjective ideas and experiences of designers and users (World 2).

In terms of the Peffers et al. model, our research process included realizing a problem situation (activity 1), analyzing published literature for ideas (activity 2), developing prototype pattern solutions, and testing these prototypes in practice, both personally and with others. Testing and revising prototypes of the proposed solution patterns have occurred through expert review, with preliminary versions exposed to researchers and students in classes, workshops, and seminars (activity 3). A proof-of-concept demonstration of the applicability of the proposed patterns is given later in this essay with a sample of published DSR papers examined to explore the fidelity of these designs to past DSR work (activity 4). Summative evaluation has occurred in seminars with participant feedback and in the classroom where doctoral students completed assignments that applied the knowledge contribution ideas found later (activity 5). Further proof-of-use and proof-of-value analyses (Nunamaker and Briggs 2011) will follow once we see how these ideas are applied in future DSR publications.

Following this research approach, in the next three sections, we design and present improved representations of DSR concepts in the form of models, frameworks, and templates, accompanied by a demonstration of the ideas against prior work. The paper concludes with a discussion of future DSR directions yet to be explored.

## Consuming and Producing Knowledge via DSR

The first issue to consider is how to understand the activities of consuming and producing knowledge via DSR. This section examines the roles of knowledge in the two spheres of natural and artificial science, and shows how each role is valuable and how the roles are interlinked. Drawing from the economics of knowledge field, useful DSR knowledge can be divided into two distinct types (see Mokyr 2002). *Descriptive knowledge* (denoted  $\Omega$  or omega) is the “what” knowledge about natural phenomena and the laws and regularities among phenomena. *Prescriptive knowledge* (denoted  $\Lambda$  or lambda) is the “how” knowledge of human-built artifacts. Figure 1 shows that both  $\Omega$  knowledge and  $\Lambda$  knowledge comprise a comprehensive knowledge base for a particular DSR domain. Appendix B provides an expanded discussion of the DSR knowledge base and its application in DSR projects.

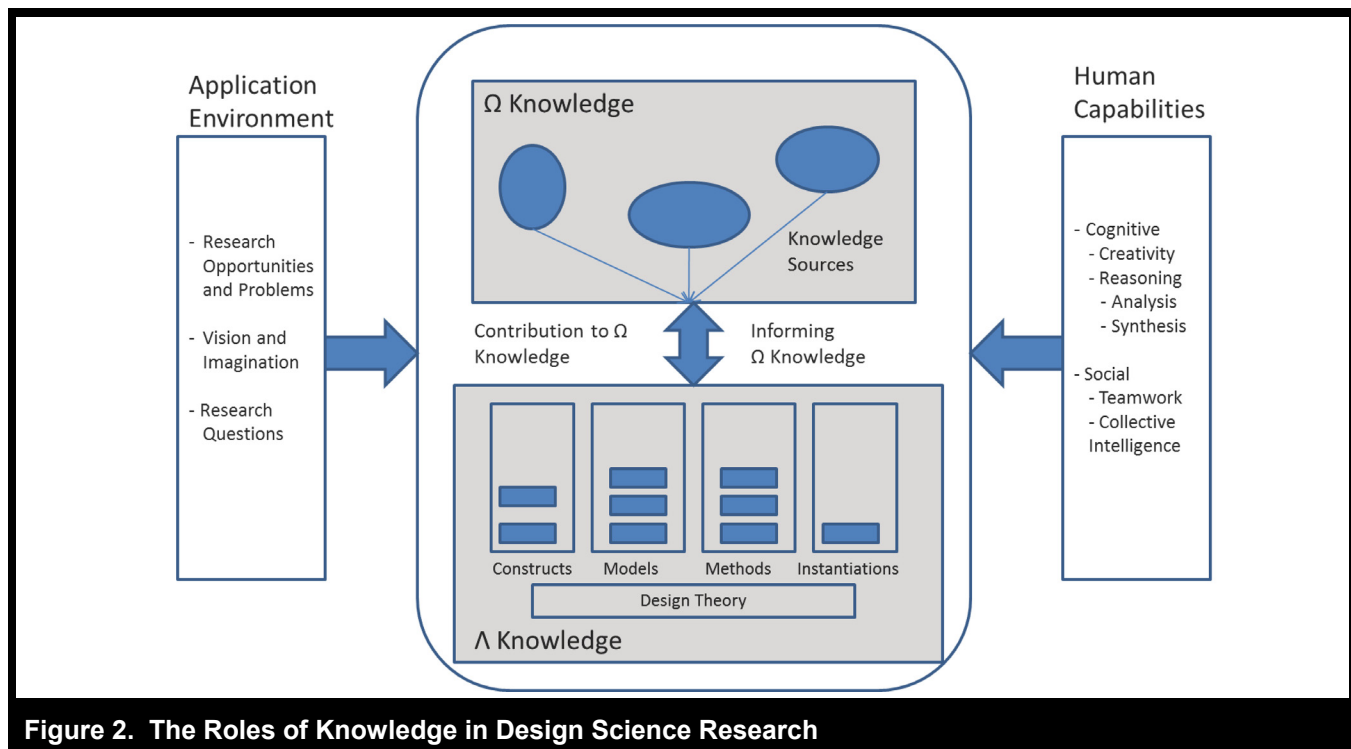
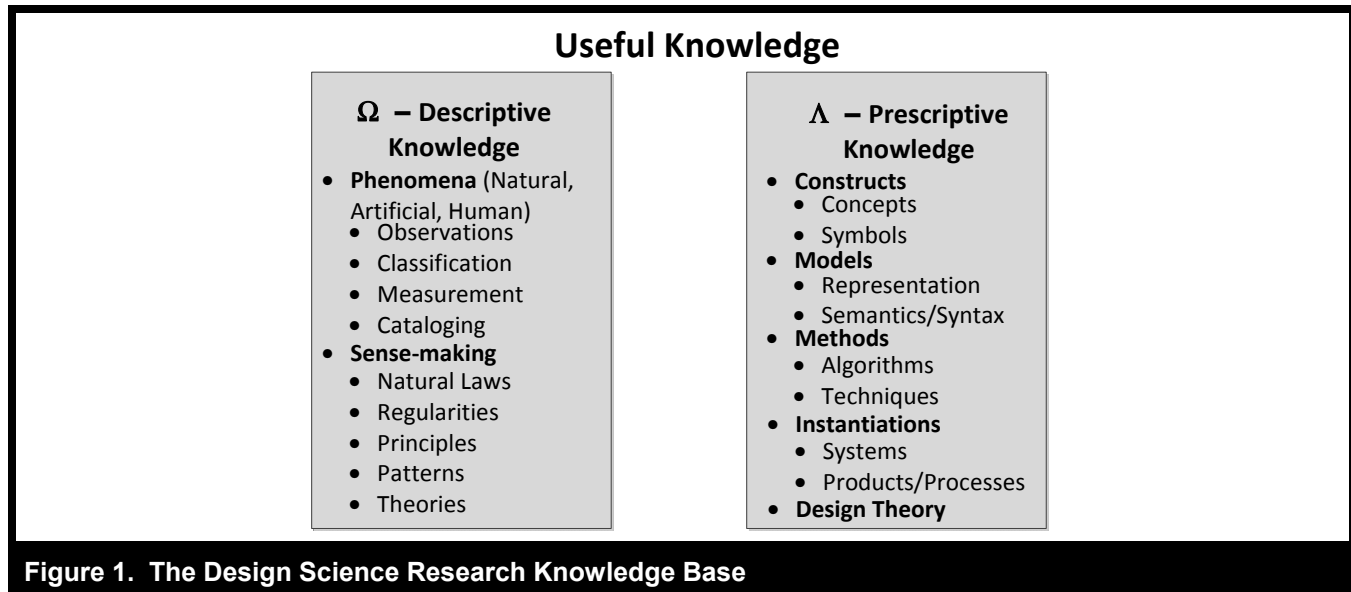
Among the key insights we explore in this essay are the various relationships and interactions of  $\Omega$  knowledge and  $\Lambda$  knowledge in the performance of DSR. Figure 2 illustrates these ideas. DSR begins with an important opportunity, chal-

lenging problem, or insightful vision/conjecture for something innovative in the application environment (Hevner 2007; Hevner et al. 2004; Iivari 2007). Research questions typically center on how to increase some measure of operational utility vis-à-vis new or improved design artifacts. To study the research questions, the first enquiry is: What do we know already? From what existing knowledge can we draw? Both  $\Omega$  and  $\Lambda$  knowledge bases are investigated for their contributions to the grounding of the research project. Such investigations are contingent on researchers having ready and efficient access to both knowledge bases.

From the  $\Omega$  base, the researcher draws appropriately relevant descriptive and propositional knowledge that informs the research questions. Relevant knowledge may be drawn from many different elements in  $\Omega$ , including existing justificatory theories that relate to the goals of the research. At the same time, from the  $\Lambda$  base, the researcher investigates known artifacts and design theories that have been used to solve the same or similar research problems in the past. The objective is to provide a baseline of knowledge on which to evaluate the novelty of new artifacts and knowledge resulting from the research. In many cases, the new design research contribution is an important extension of an existing artifact or the application of an existing artifact in a new application domain. The success of a design research project is predicated on the research skills of the team in appropriately drawing knowledge from both  $\Omega$  and  $\Lambda$  bases to ground and position the research; the teams’ cognitive skills (e.g., creativity and reasoning) in designing innovative solutions; and the teams’ social skills in bringing together all of the individual members’ collective intelligence via effective teamwork.

## The Knowledge Contribution Framework

As a focus of this essay, we present the DSR knowledge contribution framework that embodies our insights on how best to understand and position the contributions of a DSR project. Often identifying a knowledge contribution is difficult in DSR because it depends on the nature of the designed artifact (as seen in Table 1), the state of the field of knowledge, the audience to whom it is to be communicated, and the publication outlet. In addition, the degree of knowledge contribution can vary: there might be incremental artifact construction or only partial theory building, but this may still be a significant and publishable contribution because it is “new to the world.” Further, the size of the knowledge increase could be offset by the practical impact in a knowledge area.

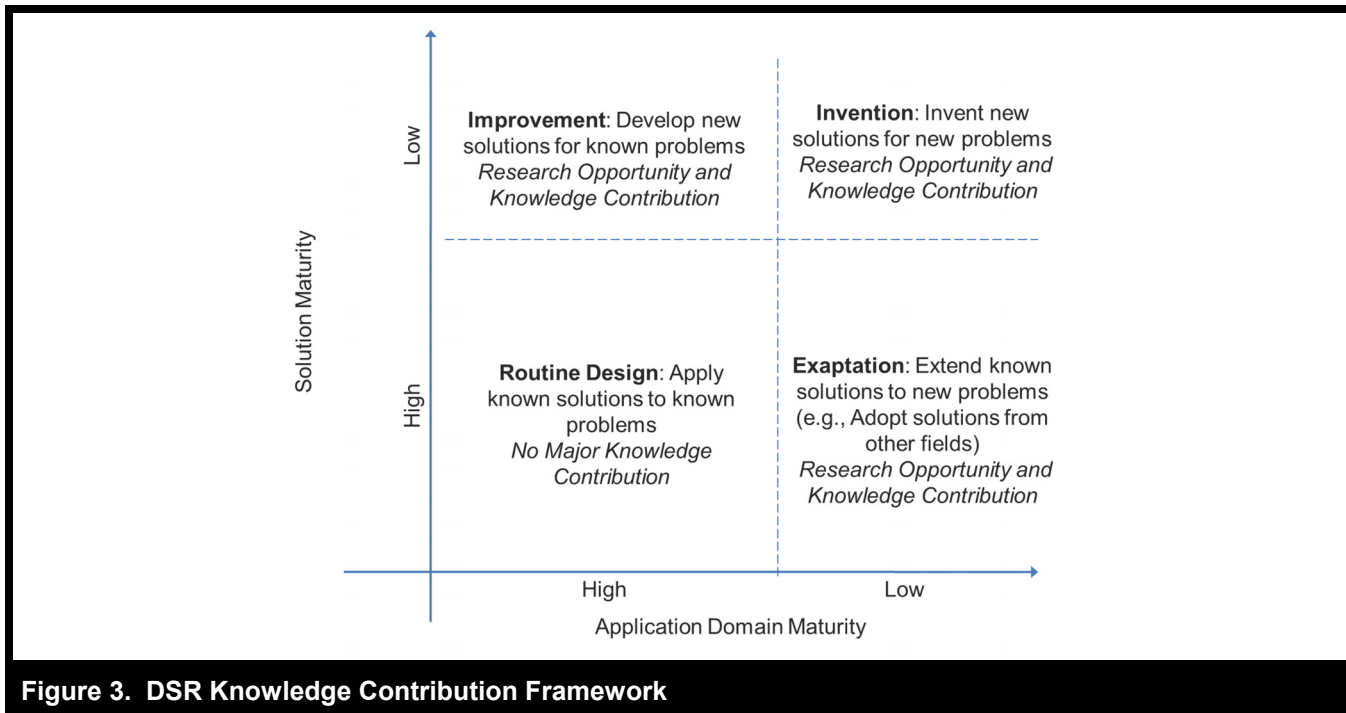


A fundamental issue is that nothing is really “new.” Everything is made out of something else or builds on some previous idea. When is something really novel or a significant advance on prior work? A DSR project has the potential to make different types and levels of research contributions depending on its starting points in terms of *problem maturity* and *solution maturity*. This variation reflects the research

project’s placement along the timeline of knowledge growth in the discipline (see Appendix B) and is related to the problem maturity and solution maturity available and relevant to the DSR project.

Figure 3 presents a  $2 \times 2$  matrix of research project contexts and potential DSR research contributions. The x-axis shows





**Figure 3. DSR Knowledge Contribution Framework**

the maturity of the problem context from high to low. The y-axis represents the current maturity of artifacts that exist as potential starting points for solutions to the research question, also from high to low.

This framework does not have any obvious counterparts in prior literature. Colquitt and Zapata-Phelan (2007) present a taxonomy to classify theoretical contributions from empirical papers, but they use theory testing and theory building as the dimensions of their  $2 \times 2$  matrix. The framework in Figure 3 differs in that theory building and theory testing activities, all part of an overarching research cycle, can complement each other in any one of the cells (except, perhaps, the routine design cell). Some similar concepts can be found in work on creativity and innovation, where the processes by which existing knowledge is transformed into new, useful products are examined (e.g., Savransky 2000; Sternberg et al. 2002). This work, however, deals more with the processes of creativity and is less structured than our matrix. We also acknowledge a possible comparison with Stokes' (1997)  $2 \times 2$  model of scientific research that has axes of practical use (x-axis) and fundamental knowledge (y-axis). While these concepts may be intuitive, it would be difficult to predict where to place a proposed project on the Stokes matrix *a priori*. Our framework focuses attention on the knowledge start-points (e.g., maturities) of the research project to support a clearer understanding of the project goals and the new contributions to be achieved.

We proceed to discuss the quadrants of Figure 3. In each quadrant, we briefly describe the contextual starting points of the research in terms of problem and solution knowledge foundations. Exemplars of work in this quadrant are explored. For each quadrant, we discuss the type of contribution that can be made in terms of different levels of artifact/theory in DSR and also in terms of contribution to and flow between  $\Omega$  and  $\Lambda$  knowledge bases. Note that, in discussing the knowledge flows, we are talking about the flows within the IS/IT knowledge bases, not the flows to reference disciplines outside IS. The latter is important but beyond the scope of this essay.

### ***Invention: New Solutions for New Problems***

True invention is a radical breakthrough—a clear departure from the accepted ways of thinking and doing. Inventions are rare and inventors are rarer still. The invention process can be described as an exploratory search over a complex problem space that requires cognitive skills of curiosity, imagination, creativity, insight, and knowledge of multiple realms of inquiry to find a feasible solution. While this process of invention is perhaps ill-defined, invention activities can still be considered DSR when the result is an artifact that can be applied and evaluated in a real-world context and when new knowledge is contributed to the  $\Omega$  and/or  $\Lambda$  knowledge bases.

DSR projects in this quadrant will entail research in new and interesting applications where little current understanding of the problem context exists and where no effective artifacts are available as solutions. In fact, so little may be known about the problem that research questions may not even have been raised before. Research contributions in this quadrant result in recognizably novel artifacts or inventions. In this category appear artifacts where the idea of the artifact itself is new; for example, the first bicycle or the first decision support system. This type of work does not fit neatly with some models of DSR where the first step is shown as “define the research problem and justify the value of a solution” (see Peffers et al. 2008). Here, a recognized problem may not necessarily exist and the value of a solution may be unclear. As Simon (1996) says, the researcher may be guided by nothing more than “interestingness.” In part, a key contribution is the conceptualization of the problem itself.

Exhibit 1 illustrates a well-known exemplar of *invention* in the IT field. Agrawal et al. (1993) developed what appears to be the first full conceptualization of mining databases for association rules as well as an efficient method for discovering them. As an invention, this paper has generated and influenced a whole new field of research. Other examples of IT inventions would include the first thinking on decision support systems (DSS) by Scott-Morton (1967), and the subsequent evolution of DSS into executive support systems (ESS) (Rockart and DeLong 1988) and group decision support systems (GDSS) (Nunamaker et al. 1991b).

Most research papers that fall into the invention category are at the artifact/instantiation level. We cannot find a single example where an invention has been advanced as design theory before it was demonstrated in a physical artifact. In history, perhaps Vannevar Bush’s idea of the Memex or Charles Babbage’s idea of a calculating machine are the closest. There are no examples of mid-range theories or grand design theories that have been advanced as inventions. Usually, as Merton says, such theories have to build on an accumulation of knowledge about a range of artifacts all addressing the same application problem—which means the problem is known and, thus, not in the invention quadrant.

Knowledge flows in the invention quadrant are typically from prescriptive to descriptive. The new artifact is invented and then other researchers see it employed in use and begin to formulate descriptive knowledge about its use in context (in a different quadrant). Within the IS knowledge base, if descriptive knowledge exists about the artifact-type, then it is not a novel application domain (it has high application maturity). However, kernel theory from outside the IS knowledge base could be used to give ideas for parts of the design.

### **Improvement: New Solutions for Known Problems**

The goal of DSR in the improvement quadrant is to create better solutions in the form of more efficient and effective products, processes, services, technologies, or ideas. Researchers must contend with a known application context for which useful solution artifacts either do not exist or are clearly suboptimal. Researchers will draw from a deep understanding of the problem environment to build innovative artifacts as solutions to important problems. The key challenge in this quadrant is to clearly demonstrate that the improved solution genuinely advances on previous knowledge.

Much of the previous and current DSR in IT belongs to this quadrant of improvement research. One example is McLaren et al.’s (2011) multilevel model for strategic fit, which addresses a need for “a more finely grained” (p. 2) tool for diagnosing strategic fit. We describe this exemplar more fully in Appendix C. Another classic example is the research stream of improvements to the GDSS literature as exemplified by Nunamaker et al. (1991a). This paper studies how the design of improved anonymity features impacts the effectiveness of option generation in negotiating groups using GDSS.

Improvement DSR is judged first on its ability to clearly represent and communicate the new artifact design. The presentation will show how and why the new solution differs from current solutions. The reasons for making the improvement should, desirably, be formally grounded in kernel theories from the knowledge base. Once the design improvement is described, then the artifact must be evaluated to provide convincing evidence of its improvement over current solutions. Improvement may be in the form of positive changes in efficiency, productivity, quality, competitiveness, market share, or other quality measures, depending on the goals of the research.

In the improvement quadrant, DSR projects make contributions to the  $\Lambda$  knowledge base in the form of artifacts at one or more levels as described in Table 1. Situated instantiations (Level 1) are often constructed to evaluate the level of improvements in comparison with instantiations of the existing solution artifacts. As appropriate, more general artifacts (Level 2) in the form of constructs, methods, models, and design principles are proposed as research improvements. In addition, new  $\Lambda$  knowledge may be formulated as mid-range design theory (Level 3) as a result of improved understandings of the problem and solution spaces. Further, the evaluations of the improved artifact may lead to knowledge contributions to the  $\Omega$  knowledge base in the form of

expanded understanding of the kernel theories or the development of new behavioral theories of the artifact in use.

### **Exaptation: Known Solutions Extended to New Problems**

Original ideas often occur to individuals who have experience in multiple disciplines of thought. Such training allows interconnections and insights among the fields to result in the expropriation of artifacts in one field to solve problems in another field. Thus, we may face a research situation in which artifacts required in a field are not available or are suboptimal. However, effective artifacts may exist in related problem areas that may be adapted or, more accurately, exapted<sup>5</sup> to the new problem context. In this quadrant are contributions where design knowledge that already exists in one field is extended or refined so that it can be used in some new application area.

This type of research is common in IS, where new technology advances often require new applications (i.e., to respond to new problems) and a consequent need to test or refine prior ideas. Often, these new advances open opportunities for the exaptation of theories and artifacts to new fields. Exemplars of exaptation in IS research include Berndt et al.'s (2003) research on the CATCH data warehouse for health care information where well-known methods of data warehouse development (e.g., Inmon 1992) are exapted to new and interesting areas of health information systems and Chaturvedi et al.'s (2011) design principles for the user experience in virtual worlds where the user experience in this context could be expected to be significantly different from online experiences in general. Another recent example of exaptation is the design of an embodied conversational agent (ECA) based kiosk for automated interviewing (Nunamaker et al. 2011). This project exapts existing artifacts of sensors and intelligent agents for innovative design of systems for use in automated deception detection.

In exaptation research, the researcher needs to demonstrate that the extension of known design knowledge into a new field is nontrivial and interesting. The new field must present some particular challenges that were not present in the field in which the techniques have already been applied. In the exaptation quadrant, similarly to the improvement quadrant, DSR can make contributions to the  $\Lambda$  knowledge base in the

form of artifacts at all three levels as appropriate to the research project goals.  $\Omega$ -knowledge contributions may also be produced via a greater understanding of the new artifacts in use.

### **Routine Design: Known Solutions for Known Problems**

Routine design occurs when existing knowledge for the problem area is well understood and when existing artifacts are used to address the opportunity or question. Research opportunities are less obvious, and these situations rarely require research methods to solve the given problem. In this quadrant is work that would **not normally** be thought of as contributing to research because existing knowledge is applied in familiar problem areas in a routine way. However, routine work may in some cases lead to surprises and discoveries (see Stokes 1997); but, in such cases, these discoveries will likely involve moving the research to one of the other quadrants.

It is important that high-quality professional design or commercial system building be clearly distinguished from DSR. Professional design is the application of existing knowledge to organizational problems, such as constructing a financial or marketing information system using "best practice" artifacts (constructs, models, methods, and instantiations) that exist in the knowledge base. The key differentiator between professional design and DSR is the clear identification of contributions to the  $\Omega$  and  $\Lambda$  knowledge bases in DSR and the communication of these contributions to the stakeholder communities.

### **Applying the Knowledge Contribution Framework**

We examined a sample of DSR articles in a leading IS journal to determine if the knowledge claims in the articles are classifiable according to the contribution framework we have proposed. (Note that some of these articles may not have identified themselves as DSR at the time of publication.) The sample includes 13 DSR articles published in *MIS Quarterly* from 2006 to 2011 inclusive. Table 2 shows the results of this classification process and the evidence for the placement of the contribution in one of the four quadrants. The two authors performed the classification process independently and there were no disagreements about placement in a specific quadrant.

This analysis shows that authors used arguments to justify their contributions in DSR that match the three "contribution"

<sup>5</sup>In biological evolution, *exaptation* is the adaptation of a trait for a different purpose from its original purpose. The classic example, featured in Gould and Vrba (1982), is the exaptation of bird feathers to the purposes of flight from the original purported purposes of bodily temperature regulation.

**Table 2. DSR Articles in MISQ 2006-2011 Classified by Knowledge Contribution Type**

Knowledge Contribution	Article	Knowledge Contribution Claims
Improvement	A Multilevel Model for Measuring Fit Between a Firm's Competitive Strategies and Information Systems Capabilities (McLaren et al. 2011)	<i>There is a need for a <b>more fine-grained model</b> for diagnosing the individual IS capabilities that contribute to the overall fit or misfit between a firm's competitive strategies and IS capabilities (p. 2) (see also Appendix C, Table C1).</i>
Improvement	Guidelines for Designing Visual Ontologies to Support Knowledge Identification (Bera et al. 2011)	<i>There could be several ways to address OWL's inability to show state changes... We have taken a different path, taking the view that we can keep the existing OWL syntax and <b>improve</b> the extent to which it supports knowledge identification (pp. 885-886).</i>
Exaptation	Co-creation in Virtual Worlds: The Design of the User Experience (Kohler et al. 2011)	<i>While Nambisan and his colleagues provide a useful framework for the online environment in general, <b>little is known about designing co-creation experiences in virtual worlds</b> (p. 774).</i>
Exaptation	Design Principles for Virtual Worlds (Chaturvedi et al. 2011)	<i>ABVWs comprise a new class of information systems... Thus, they require <b>an extension</b> of the corresponding information system design principles (p. 675)</i>
Improvement	Correlated Failures, Diversification, and Information Security Risk Management (Chen et al. 2011)	<i>While our model to estimate security loss due to unavailability (i.e., system downtime) <b>is based on well-established queuing models</b>, <b>one innovation of our model</b> is that the distribution from which the number of requests sent to the queue is drawn is endogeneous to system variables (p. 399).</i>
Exaptation	The Effects of Tree-View Based Presentation Adaptation on Mobile Web Browsing. (Adipat et al. 2011)	<i>Presentation adaptation has been studied in the desktop environment and has been proven beneficial ... <b>However, research on adaptation of Web content presentation for mobile handheld devices is still rare</b> (p. 100).</i>
Improvement	Improving Employees' Compliance Through Information Systems Security Training: An Action Research Study (Puhakainen and Sipponen 2010)	<i>There is a need for IS security training approaches that are theory-based and empirically evaluated (p. 757). To address this deficiency ... this paper <b>developed a theory-based training program</b> ... This paper then tested the practical workability through an action research intervention (p. 776).</i>
Improvement	Detecting Fake Websites: The Contribution of Statistical Learning Theory (Abbasi et al. 2010)	<i>Systems grounded in SLT <b>can more accurately detect</b> various categories of fake web sites (p. 435).</i>
Improvement	The Design Theory Nexus (Pries-Heje and Baskerville 2008)	<i>The work suggests that the design theory nexus approach <b>is more universal</b> than previous approaches to contingency theory, because it can operate in both symmetrical and asymmetrical settings (p. 748).</i>
Improvement	Process Grammar as a Tool for Business Process Design (Lee et al. 2008)	<i>The method <b>improves on existing approaches</b> by offering the generative power of grammar-based methods while addressing the principal challenge to using such approaches (p. 757).</i>
Improvement	Making Sense of Technology Trends in the Information Technology Landscape: A Design Science Approach (Adomavicius, et al. 2008)	<i>Our approach <b>may complement</b> existing technology forecasting methods ... by providing structured input and formal analysis of the past and current states of the IT landscape (p. 802).</i>
Improvement	CyberGate: A Design Framework and System for Text Analysis of Computer-Mediated Communication (Abbasi and Chen 2008)	<i>The results revealed that the CyberGate system and its underlying design framework <b>can dramatically improve</b> CMC text analysis capabilities over those provided by existing systems (p. 811).</i>
Improvement	Using Cognitive Principles to Guide Classification in Information Systems Modeling (Parsons and Wand 2008)	<i>Despite the importance of classification, no well-grounded methods exist (p. 840). We provide empirical evidence...that the rules can guide the construction of semantically <b>clearer and more useful models</b> (p. 858).</i>

quadrants in Figure 3. There were no papers that matched the “Routine Design” quadrant. As might be predicted, there were also no papers that fell into the “Invention” quadrant—pure invention is valuable but unfortunately rare. A surprising finding was that 10 of the 13 surveyed papers fell into the “Improvement” quadrant while only 3 were in the “Exaptation” quadrant. We believe this finding to be unusual based on our awareness of a fairly large number of projects in IS that would be classified in the “Exaptation” quadrant.

As another testimony to the usefulness and ease of learning of the knowledge contribution framework, during May 2011, one of the authors presented the framework to a class of 15 IS/CS doctoral students at a large European university. An assignment required the students to take a DSR paper of their own research interest and critique its research contributions to include classifying the contribution according to the framework. The students had little difficulty in placing the papers into quadrants with clear rationales for doing so.

## Design Science Research Publication Schema

Once the research team has correctly positioned their DSR contributions with respect to the appropriate knowledge bases, the challenge becomes communicating the new ideas to the stakeholder communities. The design community lags the behavioral community in having useful templates for communicating knowledge contributions. Helpful advice for preparing behavioral research for publication is provided by numerous authors including Bem (2003) for psychology, Perry (1998) for marketing, MacKenzie et al. (2011) for management and IS, and Neumann (2006) for the social sciences in general.

Some basic guidance on presenting DSR knowledge contributions is given in work including Hevner et al. (2004), Hevner and Chatterjee (2010), Peffers et al. (2008), Sørensen (2002), Vaishnavi and Kuechler (2008), Zobel (2005), and Sein et al. (2011), although this guidance is not highly detailed and thus does not approach the depth of discussion in the behavioral science literature. In addition, the treatment of publication schema for DSR is scant. In part, this problem arises because much of the work on DSR sees the development of the artifact itself as the whole point and, accordingly, there has been little emphasis on what it means to make a contribution to generalized knowledge. Thus, we conclude that the literature provides insufficient advice on how DSR is communicated and its contributions to knowledge established.

Table 3 outlines a publication pattern for a DSR study. The aspects of the pattern that are similar to a conventional paper in the behavioral science empirical mode (as in Bem 2003) are italicized. Note that other patterns are possible and many articles will not include every component that is sketched below; this suggested pattern is not meant to be overly prescriptive. Appendix C shows an example of a paper illustrating the schema.

## Publication Schema for a Design Science Research Study

### (1) Introduction Section

For DSR, the problem definition and research objectives should specify the *purpose and scope* of the artifact to be developed (what the system is for). The purpose gives the set of meta-requirements or goals for the artifact and shows the boundary of any design theory. It is also important to identify *the class of problems* (McKenney and Keen 1974) to which this specific problem belongs, which helps with placing the work against prior literature and showing its contribution clearly (see Sein et al. 2011). The *relevance* of the research problem to real-world practice must be clearly stated. A simple example to show the artifact’s purpose (as in a simple use case) can help orient the reader to the following discussion. The claims for contributions to practice and knowledge/theory should also be made here and be expanded on later.

### (2) Literature Review Section

The literature survey should include relevant descriptive theory from  $\Omega$ , prior prescriptive knowledge or existing artifacts from  $\Lambda$ , and any knowledge that is relevant to the problem at hand. It is essential to carry out this survey carefully and to include work that may have been performed under a different label with similar aims. For example, work in business analytics should look at work generally in decision support (if this is the class of problems to which this problem belongs). If this survey is not done carefully, the developed artifact risks not being really new and it will not be possible to demonstrate an unquestioned claim to a contribution to knowledge.

Included here is any *justificatory knowledge (kernel theory)* that was used to inform the construction of the new artifact. The exact placement of the justificatory theory can require some judgement. An outline of the justificatory knowledge may be given in this section, although it may make more sense

**Table 3. Publication Schema for a Design Science Research Study**

Section	Contents
1. Introduction	<i>Problem definition, problem significance/motivation, introduction to key concepts, research questions/objectives, scope of study, overview of methods and findings, theoretical and practical significance, structure of remainder of paper.</i> For DSR, the contents are similar, but the problem definition and research objectives should specify the <b>goals</b> that are required of the artifact to be developed.
2. Literature Review	<i>Prior work that is relevant to the study, including theories, empirical research studies and findings/reports from practice.</i> For DSR work, the prior literature surveyed should include any prior design theory/knowledge relating to the class of problems to be addressed, including artifacts that have already been developed to solve similar problems.
3. Method	<i>The research approach that was employed.</i> For DSR work, the specific DSR approach adopted should be explained with reference to existing authorities.
4. Artifact Description	A concise description of the artifact at the appropriate level of abstraction to make a new contribution to the knowledge base. This section (or sections) should occupy the major part of the paper. The format is likely to be variable but should include at least the description of the designed artifact and, perhaps, the design search process.
5. Evaluation	Evidence that the artifact is useful. The artifact is evaluated to demonstrate its worth with evidence addressing criteria such as validity, utility, quality, and efficacy.
6. Discussion	<i>Interpretation of the results: what the results mean and how they relate back to the objectives stated in the Introduction section. Can include: summary of what was learned, comparison with prior work, limitations, theoretical significance, practical significance, and areas requiring further work.</i> Research contributions are highlighted and the broad implications of the paper's results to research and practice are discussed.
7. Conclusions	<i>Concluding paragraphs that restate the important findings of the work.</i> Restates the main ideas in the contribution and why they are important.

to show details along with the specific aspect of the design to which it refers in the Artifact Description Section.

### (3) Method Section

For DSR work, the specific DSR approach adopted should be explained, with reference to existing authorities (e.g., Hevner et al. 2004; Nunamaker et al. 1990-91; Peffers et al. 2008; Sein et al. 2011). Clear rationales for the selections of design (build and evaluate) methods appropriate for the research project must be provided. **Research rigor** is the driving goal for methods selection.

### (4) Artifact Description Section

This section differs markedly from articles adopting the typical format of a behavioral science empirical article (as in Bem 2003). Several sections may be needed and will likely

occupy a major portion of the paper. The format may be variable but should include at least the description of the **design artifact** and, perhaps, the **design search (development) process** that led to the discovery of the artifact design. Presenting the design search process might assist in demonstrating credibility. For example, it could describe an iterative design with intermediate test stages, where the testing and evaluation is formative, part of the development process, and is likely to include basic tests of validity using test data, scenarios, and simple experimentation.

There is likely to be a variety of ways in which the material in this section is presented and there are likely to be different design practices depending on the type of artifact and the research outlet. The format for presenting a computer science/software engineering "IT product" artifact will be different from that used with an IS "socio-technical artifact" where an intervention in a social system (community or organizational) will have occurred (Niederman and March 2012). Further, there is often difficulty representing the

design of a complex artifact in the space that is allowed in a journal.

## (5) Evaluation Section

The artifact is evaluated in terms of criteria that can include validity, utility, quality, and efficacy. Validity means that the artifact works and does what it is meant to do; that it is dependable in operational terms in achieving its goals. The utility criteria assesses whether the achievement of goals has value outside the development environment. A rigorous *design evaluation* may draw from many potential techniques, such as analytics, case studies, experiments, or simulations (see Hevner et al. 2004) and naturalistic evaluations (Carlsson 2010). Further sources for methods of evaluation include Pries-Heje et al. (2008) and Sein et al. (2011).

Any evidence for the worth of the artifact should be given: for example, final summative tests in case studies or experiments, expert review, simulations, statistics on usage data for implemented systems, and evidence of impact in the field. It is important to note that some degree of flexibility may be allowed in judging the degree of evaluation that is needed when new DSR contributions are made—particularly with very novel artifacts, a “proof-of-concept” may be sufficient. When a researcher has expended significant effort in developing an artifact in a project, often with much formative testing, the summative (final) testing should not necessarily be expected to be as full or as in-depth as evaluation in a behavioral research project where the artifact was developed by someone else.

## (6) Discussion Section

Bem (2003) says that this section should go back to generalities as far as possible. A summary of what has been learned could be provided by expressing the design knowledge gained in terms of the design theory framework specified by Gregor and Jones (2007), as in the example provided by Moody (2009). For some types of artifact, particularly the “IT product” type frequently seen in computer science, this explicit identification of the theory may not be necessary for the target audience.

Further, with socio-technical artifacts in IS, when the design is complex in terms of the size of the artifact and the number of components (social and technical), then explicit extraction of design principles may be needed. This extraction/identification of the main design principles discovered/invented during the project can be difficult and a project logbook can

help with this reflection (see Spradley 1979). In this section, a claim must be reiterated for the novelty of the artifact or theory. It should be clear to the reader that bridging the “research gap” has been achieved via convincing evidence.

## (7) Conclusions Section

This section can begin with concluding paragraphs that restate the important findings of the work. The main highlights of the paper should be reiterated—the declaration of victory.

### ***Highlighting the Knowledge Contribution in a Publication***

The above schema gives an outline for the presentation of a DSR article. What is likely to be the most critical part of this presentation is how the author stakes the claim to a knowledge contribution. We need the sections on the method, artifact description, and evaluation to answer the question: Is it true? (That is, Why should I believe you?) We are still left, however, with other questions: Is it new? Is it interesting? Has there been a genuine contribution to knowledge? Readers must be convinced of affirmative answers to all three for a top journal quality publication.

How does one do this effectively? As with behavioral science papers, this task is not an easy one and, in part, relies on an author’s experience and ability to tell a story. Nevertheless, by drawing on the views offered earlier, it is possible to offer some guidelines. The underlying principle is that authors should understand and convey how their work fits in the process of developing mature bodies of design knowledge and theory.

The introductory section is of the utmost importance because of first impressions. It is here that one can highlight the practical importance of the problem, thereby adding to the interestingness of the work. For example, Agrawal et al. (1993) begins with the statement: “Consider a supermarket with a large collection of items,” which immediately demonstrates in simple language that a practical problem is being addressed. It is also important in the introductory section to position the paper against both the existing state of knowledge for the problem area (if any) and also the type of contribution you are making in terms of the knowledge contribution framework. The overarching problem area needs to be identified at the highest level possible (the classic concern), and the deficiencies or gaps in knowledge identified. Of course, the claims that are made about the existing state of knowledge must be supported in the following literature review section.

Then the type of contribution being made—either *invention*, *improvement*, or *exaptation*—can be stated. The contribution can be clearly expressed in terms of whether it is extending a relatively mature design theory from another field (exaptation quadrant), offering a nascent theory to a well-known problem where existing theory has shortcomings (improvement quadrant), or beginning an entirely new area of thinking and practical contribution by inventing a novel artifact. This guideline is congruent with Feldman's (2004) advice to behavioral researchers to signal their intention with respect to theorizing.

The discussion and conclusions sections are the other critical sections for signaling a contribution. Authors should summarize what was learned and analyze this new knowledge against prior work to show that it is an advance on previous knowledge. First, the design evaluation must provide convincing evidence that the research makes a practical contribution to the application context. Only then can the researchers reflect on this contribution and formulate the knowledge contributions to the general field. We suggest that, perhaps, apart from the invention quadrant, the new knowledge is likely to be more highly regarded the further up the levels of abstraction it can be pushed to nascent design theory or more complete design theory (Table 1). An artifact that is presented with a higher level degree of abstraction can be generalized to other situations and is more interesting than a simple descriptive case study of what happened in one situation. What separates the more comprehensive bodies of knowledge and theory from the lower level nascent theory and artifact descriptions? If we examine the components of a design theory closely (Gregor and Jones 2007), we see that it includes knowledge found also in a description of an artifact, as in meta-requirements (goal/boundary descriptions), constructs, and principles of form and function. What further distinguishes design theory is that it includes kernel theory to explain why the artifact works along with testable propositions. If research can be expressed in these terms, with more explanation, more precision, more abstraction, and more testing of beliefs facilitated, then there is a move toward a more mature and well-developed body of knowledge—our ultimate goal (Nagel 1979).

However, we also wish to caution researchers to clearly understand what contributions can be claimed in their research project. Researchers should not force results into a design theory description if such a presentation is not appropriate or useful. Often, DSR results can be presented effectively as artifact representations and rigorous evaluations of the artifact in use. Only when expression of these results in a design theory provides a useful generalization for extending knowledge in the problem or solution domains should such a design theory be presented.

## Discussion and Conclusions

This essay addresses the issues associated with knowledge contributions in design science research in IT-related fields, including information systems. It aims to assist researchers in identifying appropriate ways of consuming and producing knowledge when they are preparing journal or other scholarly works and to assist editors, reviewers, and readers in more easily identifying the degree of contribution made by a research study. The essay also aims at clarifying some perceived confusions in terminology and the types of contributions from DSR. To these ends, the paper has developed a *DSR knowledge contribution framework* and a *DSR publication schema* as DSR knowledge contributions.

As with any work of this type, the proposed contribution framework and publication schema should be seen as guidelines; they are not meant to be followed blindly or serve as a straightjacket for future work. Researchers should be able to exercise their discretion to vary what is proposed or to suggest and implement improvements. Likewise, editors and reviewers of DSR papers should not use deviations from the framework and schema as primary reasons to reject good DSR work. The structure of articles could vary to some extent depending on the type of contribution made: that is, the applicable quadrant in Figure 3. For example, work in quadrant 1 (invention) may have less to say about kernel theory than other types of contribution. Our goal here is to provide informative structure to DSR thinking, not to limit and constrain it.

Further, there are still difficulties in presenting DSR that have barely been explored here and could be addressed in future work. One issue is that the extraction of the key principles that underlie a design, as compared with parts of the design that may be more mundane or routine, can be extremely difficult. It is recommended that a project logbook be kept throughout a project to record important design problems and proposed solutions. This recording can help with the later identification of important design principles. Spradley's (1979) recommendations for keeping field notes may be helpful.

A second issue is that a genuine new invention is a difficult goal for DSR research projects and we can expect few contributions to fall in the invention quadrant. However, exploration for new ideas and artifacts should be encouraged regardless of the hurdles. Research in the invention quadrant can be difficult to get published as reviewers find it difficult to cope with the "newness." Some typical problems include the design being insufficiently grounded in kernel theories, the design being incomplete, the design not being rigorously



evaluated, or there being no new contribution to theory made via the design. While such concerns may be valid, we would hope that reviewers and editors can be more accepting of newness in domains marked by less mature knowledge bases of problems and solutions. After all, new knowledge must begin somewhere.

A third issue is the difficulty of describing the complexities of an artifact within the confines of a journal article. As stated previously, the level of design detail in a journal paper will vary based on the application domain, the designed artifact, and the audience to which the presentation is made. We envision increased use of online appendices, data repositories, and executable systems to supplement DSR presentations in journals.

To conclude, this paper contributes to the IS community because prior work has not adequately addressed the important question that we have tackled here: How can design science research make and demonstrate a significant knowledge contribution? Our goal is to establish some consensus on guidelines by which DSR research, as it is communicated to other scientists, can be judged.

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## POSITIONING AND PRESENTING DESIGN SCIENCE RESEARCH FOR MAXIMUM IMPACT

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## Appendix A

### Design Theorizing

Debate continues in the IS community about whether design knowledge can be given the label of “theory” (e.g., Weber 2012), although this debate is possibly largely a matter of semantics or personal preference. There is the further question of how artifact development contributes to the process of design theorizing. We briefly address these questions in turn below.

In the natural and social sciences, well-developed or mature theory refers to a cohesive body of knowledge that has certain distinguishing characteristics. “Scientific” knowledge, as opposed to common-sense or pre-scientific knowledge, has (1) explanations of why statements and beliefs hold; (2) delimitation of the boundaries within which beliefs hold; (3) a logically consistent set of statements and beliefs; (4) precision in the language used to specify constructs and statements; (5) abstraction in the formulation of generalized concepts and statements; and (6) persistent testing of arguments and beliefs against available evidence (Nagel 1979, pp. 2-14). In our view, the work by Gregor and Jones (2007) provides good arguments to show that well-developed design knowledge can satisfy these criteria for scientific knowledge and also the criteria for theory that Dubin (1978) specifies. In this paper, we consider “mature” and “well-developed theory” as broadly equivalent to the concept of a well-developed, cohesive, and consistent body of knowledge, or knowledge system, as Nagel (1979) describes.

We argue that the initial development of artifacts and their description is akin to the discovery of an “experimental law” (Nagel 1979) or an “empirical generalization” in other branches of science—“an isolated proposition summarizing observed uniformities of relationships between two or more variables” (Merton 1968, p. 41). An empirical generalization is comparable to a technological rule in design knowledge: that is, in order to achieve something similar to Z in situation Y, then perform X (Bunge 1998). In Merton’s terms, knowledge of the behavior of individual artifacts (basic observations and empirical generalizations) is needed before a system of thought (theory) can be developed (pp. 46-47).

With DSR in many fields, the development of a particularly novel artifact with high utility will be seen as a contribution to knowledge, even if the full understanding of why the artifact works is partial and incomplete. Evaluation of the artifact with quantitative measures of effectiveness provides the empirical evidence for theory development. Simon (1996) gives the example of the first operating system where the principles behind its architecture were only partly understood.

As with other forms of theory, design theory must have some degree of generality. Walls, Widmeyer, and El Sawy (1992), early proponents of design theory in IS, stress that design theory must include components that are at a meta-level. A set of *meta-requirements* is needed to

specify “the class of goals to which the theory applies.” A design theory “does not address a single problem but rather a class of problems” (p. 42). Similarly, a design theory encompasses a *meta-design* that describes a class of artifacts that meets the meta-requirements.

In sum, we argue that a body of mature design knowledge can be given the label “theory” as it possesses similar characteristics to other forms of theory in the sciences. Further, as in other branches of science, contributions to knowledge can take many forms and be at different interim stages of theorizing.

## Appendix B

### Types of Knowledge in Design Science Research

This appendix provides foundational material to our presentation of how DSR relates to essential knowledge and its growth in the world.

#### A Brief History of Knowledge

Distinctions among types of knowledge and their different roles date back to the earliest days of philosophy, which includes the early Greek philosophers. Aristotle distinguished between *epistêmê* and *technê*, where *epistêmê* is scientific knowledge that is universal and eternal and *technê* is knowledge that is concerned with production and action and underlies the coming into being of something (an artifact), contingent on the existence of a producer to cause the thing to come into being. Other approaches to knowledge were also distinguished, such as *phronesis*, which has a meaning similar to applied ethics, but is outside the scope of the current discussion (Parry 2008).

The distinctions between different types of knowledge have not always been sharp and Aristotle saw medicine as involving both *epistêmê* and *technê*. Modern philosophers of science have not always observed a sharp distinction either. Hempel (1966, p. 3) begins a text on the philosophy of natural science with a striking example of “scientific enquiry” in the prevention of childbed fever in an Austrian hospital by the physician Semmelweis in the 19<sup>th</sup> century. What was developed was a practical solution to a problem; in Aristotle’s terms, it was closer to *technê* rather than *epistêmê*. We opened this essay with a quote from Diderot’s *Encyclopedie* (circa 1751) on the Arts that cogently expresses the close interrelationship between theory (*epistêmê*) and technique (*technê*). Thus, as seen in Figure 1 in the main text, knowledge can be divided into two related types: descriptive knowledge and prescriptive knowledge.

#### Descriptive Knowledge

Descriptive knowledge has two primary forms. The descriptions of natural, artificial, and human-related phenomena are composed of observations, classifications, measurements, and the cataloging of these descriptions into accessible forms. Additionally, we discover knowledge of the sense-making relationships among the phenomena. This sense-making is represented by natural laws, principles, regularities, patterns, and theories. Together, phenomena and their sense-making relationships provide the natural, artificial, and human (social) science bases for the world in which we live. An addition of knowledge to  $\Omega$  is a *discovery* of new facts or laws that had always existed but had not been understood and described until now. Descriptive knowledge, which constitutes the bulk of the natural and social sciences, is treated in-depth by authors such as Nagel (1979), and, because it is not the focus of this paper, we direct authors to such works for further reading.

Over time, the  $\Omega$  knowledge base accumulates the “body of knowledge” (BOK) surrounding a natural, artificial, social, or human phenomenon. Such knowledge resides in people’s minds or in external storage devices (e.g., data repositories in the cloud). Two key observations are important for this discussion. First, arguments about whether components of  $\Omega$  are correct or not are superfluous. Hypotheses about nature can be thought of as truthful for a long period of time and yet be regarded today as not true (e.g., the earth-centric universe or the humoral theory of disease). Who knows what  $\Omega$  “truths” today will be discarded as incorrect based on future discoveries? However, whether truthful or not, the current body of descriptive knowledge will provide the theoretical bases for the design of practical and useful artifacts.

Second, our ability to effectively exploit  $\Omega$  and  $\Lambda$  knowledge in DSR research is dependent on the efficiency and cost of access to this knowledge (Mokyr 2002). Real costs, in terms of time, effort, travel, money, and other resource constraints, may hamper and even deny a researcher’s ability to perform rigorous and relevant DSR projects. As examples of the problems of limiting access to knowledge, consider:

1. Copyright restrictions on scientific literature that limit open access to the latest journals and conference proceedings without paying access fees.

2. Excessive time periods (sometimes, years) required by peer review systems that delay the release of new theories and products (e.g., drugs and medical devices).
3. Proprietary intellectual property held by businesses that restrict researchers from fully understanding and extending artifacts such as cutting-edge Internet search algorithms and recommendation systems.

## Prescriptive Knowledge

Prescriptive knowledge concerns artifacts designed by humans to improve the natural world. Simon (1996) labels such knowledge as belonging to the sciences of the artificial. March and Smith (1995) define four types of prescriptive knowledge: constructs, models, methods, and instantiations. Design theories are also prescriptive knowledge, so the  $\Lambda$  knowledge base includes:

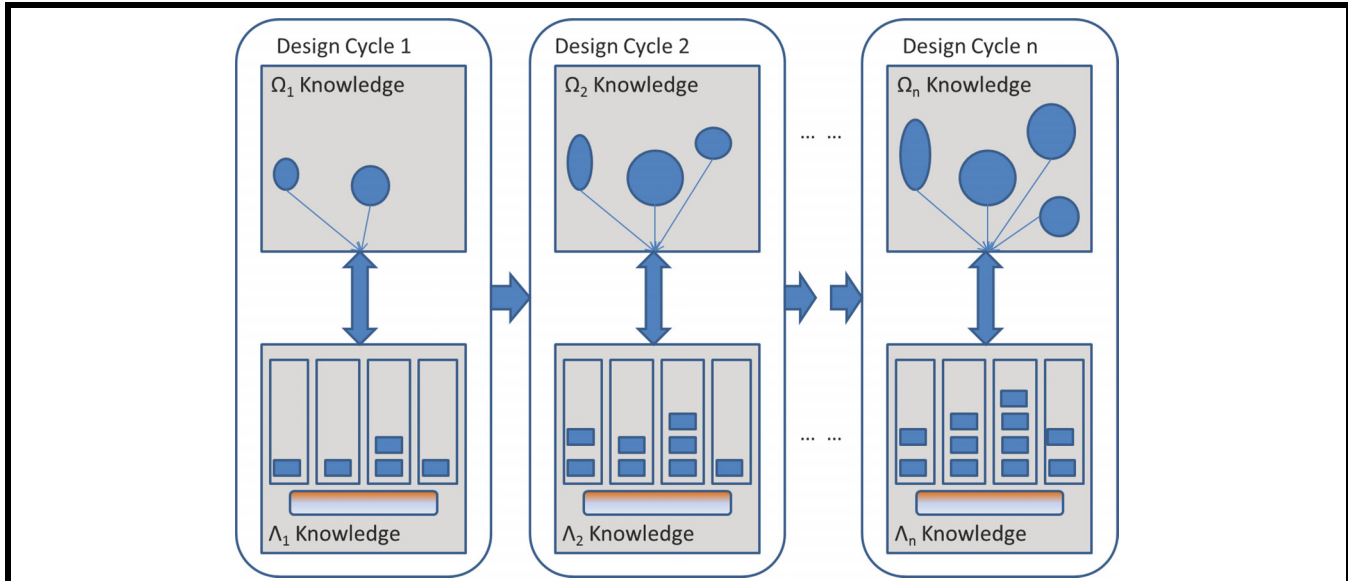
- *Constructs*, which provide the vocabulary and symbols used to define and understand problems and solutions; for example, the constructs of “entities” and “relationships” in the field of information modeling. The correct constructs have a significant impact on the way in which tasks and problems are conceived, and they enable the construction of models for the problem and solution domains.
- *Models*, which are designed representations of the problem and possible solutions. For example, mathematical models, diagrammatical models, and logic models are widely used in the IS field and new and more useful models are continually being developed. Models correspond to “principles of form” in the Gregor and Jones (2007) taxonomy: the abstract blueprint of an artifact’s architecture, which show an artifact’s components and how they interact.
- *Methods*, which are algorithms, practices, and recipes for performing a task. Methods provide the instructions for performing goal-driven activities. They are also known as techniques (Mokyr 2002), and correspond to “principles of function” in the Gregor and Jones taxonomy and Bunge’s (1998) technological rules.
- *Instantiations*, which are the physical realizations that act on the natural world, such as an information system that stores, retrieves, and analyzes customer relationship data. Instantiations can embody design knowledge, possibly in the absence of more explicit description. The structural form and functions embodied in an artifact can be inferred to some degree by observing the artifact.
- *A design theory*, which is an abstract, coherent body of prescriptive knowledge that describes the principles of form and function, methods, and justificatory theory that are used to develop an artifact or accomplish some end (Gregor 2006; Gregor and Jones 2007). Design theory can include the other forms of design knowledge: constructs, models, methods, and instantiations that convey knowledge.

Adding knowledge to  $\Lambda$  concerns *inventions*, *improvements*, and *exaptations*; that is, things that would not exist except for human creativity.

## The Growth of Knowledge over Time

We can explore the synergistic nature of knowledge growth between  $\Omega$  and  $\Lambda$ . Consider the scenario illustrated in Figure B1. Initial investigation of an exciting research question may find little available  $\Omega$  knowledge about which to guide the DSR project. In addition, few solution artifacts may apply. In this case, we have shallow knowledge bases in both  $\Omega$  and  $\Lambda$ . Thus, in design cycle 1, the research team will design artifacts based mostly on inspired creativity and trial-and-error design processes in order to address the research questions. The research contributions of design cycle 1 are the initial set of artifacts in  $\Lambda$  and the initial empirical evaluation results in  $\Omega$ . As these artifacts are employed in the application environment over time, additional behavioral research studies may be performed to increase the  $\Omega$  knowledge of their use.

At some point, design cycle 2 will begin from a new  $\Omega$  starting point. New areas of descriptive theory may be identified that help to inform a research project to extend or replace the current set of solution artifacts. (Note that the “old” artifacts and design knowledge will remain in the growing  $\Lambda$  base to provide a record of the historical evolution of the technology.) Again, the execution of design cycle 2 will add new artifact knowledge to  $\Lambda$  and new propositional knowledge to  $\Omega$ . Thus, this cycle of design improvements can continue until radical changes in the application environments and/or solution technologies create completely different research questions that make the current set of artifacts obsolete. Terming them the *innovator’s dilemma*, Christensen (2000) insightfully explores the challenges of such radical innovation periods.



**Figure B1. Evolution of Knowledge via Design Cycles**

## Appendix C

### Publication Schema Example

Here we present a recent paper that exemplifies the publication schema being proposed. Note that an examination of other published work shows some variation in the order in which the components of the schema are presented and also in the names of the components. In the papers that we examined, however, all of the components were present in some form or other except for the “research method” section, which is often missing, especially in papers published before the DSR approach was well articulated. Table C1 applies our proposed publication schema to a recent paper in *MIS Quarterly* (McLaren et al. 2011). This paper is an example of a contribution in the “improvement” quadrant, as it aims to improve on existing measurement approaches.

**Table C1. Example of Publication Schema (McLaren et al. 2011)**

Section	Contents
Introduction	Problem definition: There is a need for a more fine-grained model for diagnosing the individual IS capabilities that contribute to the overall fit or misfit between a firm's competitive strategies and IS capabilities (p. 2). Goal: to design and evaluate a new and more fine-grained measurement tool (p. 2). Relevance: Improving the strategic fit of a firm's information system has been a primary goal of IS executives for at least two decades (p. 2).
Literature Review	Reviews prior approaches and classifies them into three types. Shows the deficiencies in prior approaches (pp. 2-4).
Method	Follows Baskerville et al.'s (2009) methodology, plus exploratory research methods for developing managerial guidelines from case study evidence (Eisenhardt 1989).
Artifact Description	Describes the seven steps of the multilevel strategic fit (MSF) measurement model in detail (p. 6-12). Justificatory theory for some steps is given; for example, Conant et al. (1990).
Evaluation	The model was evaluated for reliability, validity, and utility (pp. 12-15) using data from the case studies that were used to inform the model's design. The reliability of the MSF model was evaluated by comparing outputs from the final version of the model with all the evidence gathered from the case studies (p. 13).
Discussion	The MSF measurement model is shown as an important contribution as a theory for design and action (prescriptive knowledge). Design knowledge is summarized in terms of Gregor and Jones' (2007) framework for design theory, shown in an appendix. A contribution to supply chain management is argued in terms of clearer ways of conceptualizing supply chain management (descriptive knowledge). A contribution to research methodology is also argued and implications for practice are shown. The research itself is evaluated against Hevner et al. (2004) guidelines for conducting design science research.
Conclusions	An overview of the work is given and contributions highlighted, as well as limitations and directions for further work.

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