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EDITORIAL

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Design Science Research Contributions: Finding a Balance between Artifact and Theory

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Abstract

With the rising interest in Design Science Research (DSR), it is crucial to engage in the ongoing debate on what constitutes an acceptable contribution for publishing DSR - the design artifact, the design theory, or both. In this editorial, we provide some constructive guidance across different positioning statements with actionable recommendations for DSR authors and reviewers. We expect this editorial to serve as a foundational step towards clarifying misconceptions about DSR contributions and to pave the way for the acceptance of more DSR papers to top IS journals.

Keywords: Design Science Research (DSR), Artifact, Design Theory, DSR Processes, DSR Impacts

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1 Introduction

Design science research (DSR) is a research paradigm with great potential to address the relevance versus rigour gap in information systems (IS) research. DSR brings both practical relevance (via its emphasis on useful artifacts) and scientific rigor (via the formulation of design theories) to IS research. IS prides itself as a discipline that sits at the nexus of technical research on IT, the application and business uses of IT, and the natural, social and behavioral scientific dimensions of IT (King & Lyytinen, 2006; Benbasat & Zmud, 2003). The emergence of DSR as a research approach of importance in IS can be seen in the increasing calls for greater emphasis (e.g., special issues) by leading IS journals and the panel discussions and dedicated tracks at IS conferences (Gregor & Hevner, 2011; March & Storey, 2008; Winter, 2008). However, despite the pronounced value of DSR, there still seems to be a paucity of DSR papers appearing in the top journals in the field (Goes, 2014). Why is this and what can we do about it?

A plausible explanation seems to be the requirement that the outcomes of a DSR project meet the "traditional theory contribution demands" of some gatekeepers of IS journals (Straub, 2009). With the growing acceptance of DSR as a keystone IS research paradigm, it is of utmost importance to bring clarity to the nature of DSR contributions that should suffice for scholarly publications. A common reviewer comment before a rejection—echoing the observations by Avison and Malaurent (2014)—is "where is the theoretical contribution?" In response to these concerns, we set out in this editorial to articulate the range of contributions that a DSR paper can make to both scientific and technical knowledge bases in a manner that informs and advances IS scholarship. What is the appropriate balance between making research contributions to science (theory) and technology (artifacts)?

This editorial moves beyond prior debates on design artifacts versus design theory that depict a continuum from artifact to theory (e.g., Gregor & Hevner, 2013). It provides additional insights and practical guidance while providing more in-depth perspectives on key aspects of design research knowledge contributions. Included among these insights, we posit that:

- If an artifact is novel and useful, then it necessarily contributes to design knowledge;
- The development of design theories meets the longitudinal, continuous improvement goals of DSR;
- Since DSR projects occur within a research stream, publication opportunities can occur at several points along that stream; and
- Assigning a project's research contribution to solely the design theory or the design artifact inevitably yields an incomplete understanding of DSR.

2 DSR Contributions

Two dominant types of contributions are defined as research outcomes from a DSR project—design artifacts and design theories (Gregor & Hevner, 2013; Baskerville, Lyytinen, Sambamurthy, & Straub, 2011). To clarify the positioning of DSR contributions toward providing both real-world solutions and novel inputs to knowledge, a key issue is the question of sufficiency for IS journal publication: *Must a DSR research project produce both an artifact* ***and*** *a theory? Under what circumstances would either artifact* ***or*** *theory contributions be sufficient?* These questions are valid as they get to the heart of the positioning of a DSR paper to meet the theoretical requirements of journal publication, and at the same time, to solve a practical problem or to address an interesting class of problems.

Previous discussions surrounding DSR highlight the importance of coexisting artifact and theory contributions. However, few published DSR papers can make claim for both (Hevner, March, Park, & Ram, 2004; Gregor & Jones, 2007) and fewer still address how to balance both in a meaningful way. In fact, some have argued that there are two DSR camps—the artifact camp and the design theory camp. The artifact school of thought highlights that the essential element of a DSR project should be the design artifact (Hevner & Chatterjee, 2010; Hevner et al., 2004; March & Smith, 1995). The design theory school of thought presents the design theory as a necessary and key contribution (Kuechler & Vaishnavi, 2008; Gregor & Jones, 2007; Markus, Majchrzak & Gasser, 2002). We recognize that the aim of these earlier papers was not necessarily to argue for one contribution as superior to the other, but rather to illuminate the nuances and peculiarities of the perspective focused on by each paper.

The authors of this editorial, with many years of experience in performing and reflecting about DSR, bring their unique perspectives to the question of what constitutes impactful DSR contributions for publication in top IS journals. We do not claim to present one *true* answer to this important question. Instead, collectively, our goal is to provide some constructive guidance across the different views for the use of future authors, reviewers, and editors as they produce and assess DSR publications. We expect this editorial to serve as a crucial but still preliminary step toward clarifying misconceptions about DSR contributions and paving the way for the acceptance of more DSR papers to top IS journals.

The following presentation has five DSR positioning sections and a final call to action. Each of the five sections states a position on what it means to perform quality DSR projects. The five positions support clear guidance for the production of DSR presentations amenable to publication in top IS journals. Table 1 provides a concise summary of the five DSR positions and guidance.

Table 1. Design Science Research Positioning Statements and Publication Guidance

Design Science Research Objective	Positioning statement	Publication guidance
Technology and science evolutions	DSR projects must be correctly positioned in the cycles of science-technology evolution for the chosen application domain.	• Assess the maturity of the scientific (descriptive) and technology (prescriptive) knowledge bases for the DSR project domain. • Identify the appropriate starting points for the DSR project to clearly demonstrate new knowledge contributions made by the project.
Design artifacts	A novel IT artifact must be built and evaluated in a DSR project. The design artifact most often comes before the development of nascent and mid-range design theories.	• Represent the IT artifact clearly. • Demonstrate its novelty and its practical improvements, first, then move to reflecting on design theory contributions.

Table 1. Design Science Research Positioning Statements and Publication Guidance

Design theories	The distinctive value and origins of design knowledge, as represented in both artifacts and theories, should be recognized as both inputs and outputs of a DSR project.	• Traditional kernel or reference theory to support DSR is important but is not always feasible, particularly with research that involves creativity. • Some design theorizing is expected for DSR as a reflection on the advance in design knowledge. • There is no requirement that nondesign theory contributions be made in DSR.
DSR processes	Reference processes are available for conducting DSR and these should be followed, or contributed to, through exemplar research process descriptions.	• Use a reference process for guidance in performing the research. • Reflect on the reference process when reporting research and propose process improvements as appropriate.
DSR impacts	Design artifacts should impact practice *and* design theories should impact research.	• DSR research must report the kinds of impact planned and achieved by the resulting IT artifact. • The impacts of the artifact and the design theory are cumulative, cohesive, and inseparable.

3 Positioning DSR in Technology and Science Evolutions

To begin, it is instructive to locate DSR in the larger context of the synergistic interactions of *technology* and *science* (Mokyr, 2002; Arthur, 2009; Kelly, 2010; Ridley, 2015). Figure 1 illustrates the evolutionary interplay between the activities of science and technology. The goals of science are to grow the descriptive knowledge base of the natural world and human behavior through application of the scientific method. In doing so, we gain a better understanding of how the world works. The goals of technology are to grow the prescriptive knowledge base of purposefully designed artifacts to improve human capabilities both physically (e.g., tool use) and mentally (e.g., decision-making).

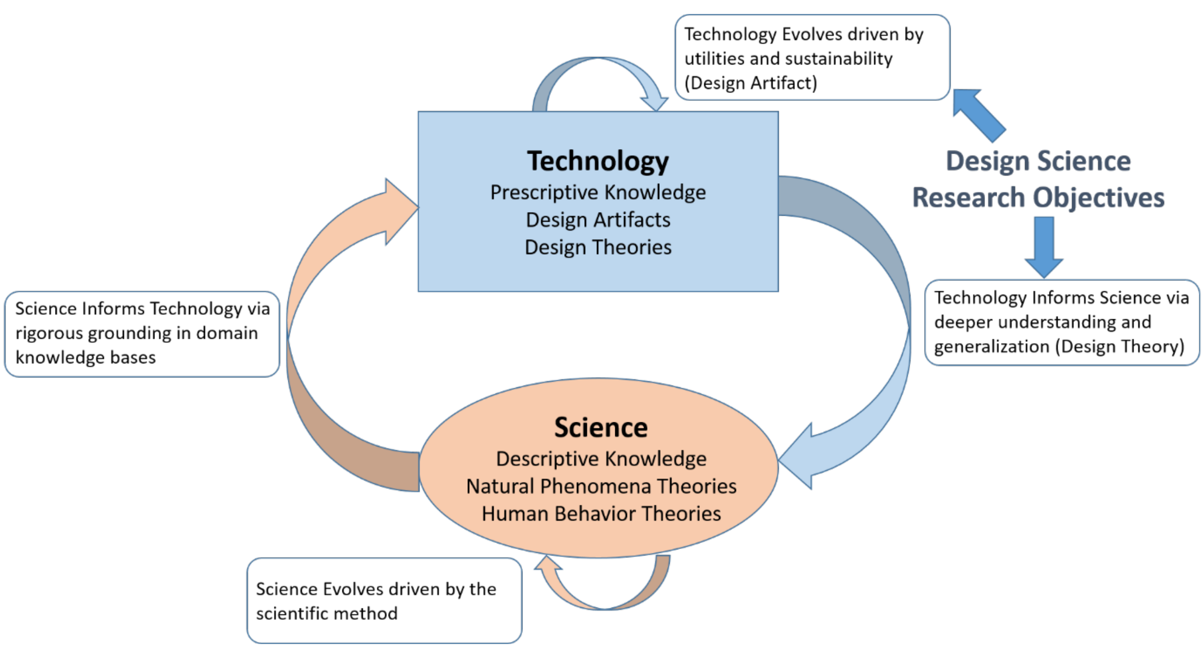

Figure 1. Technology and Science

As both science and technology advance and evolve, they display a complex set of interactions and relationships. For example, Mokyr (2002) provides a fascinating historical study of the interactions between science and technology during the industrial revolution. He expands on the interplay between the technical inventions of engineers and mechanics (e.g., steam engines, water pumps, telescopes) and the subsequent scientific reflections by natural philosophers resulting in nascent theories of thermodynamics, optics, and astronomy, among others. New technologies are driven and enabled by science, but, more often, scientific advances are driven and enabled by the emerging use of technology. While an in-depth analysis of the science-technology dualism is not possible in this editorial, the following observations are instructive to better understand the positioning of DSR in Figure 1.

- The evolution of science is slow and is marked by gradual paradigmatic shifts (Kuhn, 1996). Growth of scientific knowledge is driven by the scientific method via the development of relevant research questions, careful experimentation, the collection of empirical evidence, and rigorous hypothesis testing.
- Science informs technology via rigorous grounding in application domain descriptive knowledge bases. The search for feasible solutions is constrained by the laws of nature and applicable kernel theories in the appropriate fields of application.
- The evolution of technology can be very rapid and is marked by pervasive artifact improvements across all human fields of endeavour (Arthur, 2009; Ridley, 2015). Technology innovations are driven by the goals of enhancing human experiences, maximizing economic utilities, and building sustainable environments (Gill & Hevner, 2013).

Technology informs science by providing the opportunity to study creative solutions to relevant, real-world problems (Arthur, 2009; Kelly, 2010). The new technologies change and, hopefully, improve the world. It is then the role of the scientist to understand how and why the newly introduced IT artifacts work the way they do to achieve such positive changes. Thus, it can be posited that, in most cases, technology evolutions precede and drive science evolutions (Mokyr, 2002). As Nunamaker, Chen, and Purdin (1991) comment, "without research efforts directed toward developing new solutions and systems, there would be little opportunity for evaluative research."

3.1 DSR Contributions to Science and Technology

The important challenge, then, for design science researchers is how to position DSR projects into the science-technology evolutionary cycles of Figure 1. A researcher must be able to make clear contributions to the rapid pace of technology improvements, while at the same time provide a deeper understanding and generalization of these improvements through constructing nascent design theories in the abstract forms of models, methods, principles, and rules. These new nascent theories may then be used to inform a more deliberate and planned study of how the technology works and how it can be effectively appropriated in multiple associated application contexts. Thus, Figure 1 identifies two DSR objectives roughly corresponding to the two key contributions required in DSR:

- The design of a novel IT artifact and the introduction of the artifact into an application context with measurable improvements (technology evolution).
- The addition of new prescriptive knowledge contributions in the form of IT artifacts and nascent design theories to extend and generalize the knowledge contribution of the DSR project (technology informing science).

3.2 Scientific Theories Informing DSR

A DSR project begins with the identification of a challenging problem or opportunity in an interesting application environment. The requirements for the research are defined along with the acceptance criteria for the evaluation of the goodness of a design solution. The research team investigates the existing knowledge bases of descriptive and prescriptive knowledge to provide the scientific and technical foundations upon which new knowledge will be grown in the project (Gregor & Hevner, 2013). The existing descriptive theories (e.g., kernel theories) rigorously ground the research and inform design solutions with application appropriate natural, social, and human laws, constraints, and capabilities (Walls, Widmeyer & El Sawy, 1992). Thus, the success of a DSR project is predicated on the research skills of the team in appropriately drawing knowledge from both descriptive and prescriptive knowledge bases to ground and inform the research.

A recent debate in the IS community has proposed the use of general systems theory (GST) as an overarching scientific theory to inform the design of information systems artifacts and their theorizing (Demetis & Lee, 2016; Matook & Brown, 2017). The responses to the use of GST as a foundational theory in IS have been immediate and intense (Robey & Mikhaeil, 2016; Mingers, 2017; Schultze, 2017; Demetis & Lee, 2017). A variation of GST in the form of sociotechnical systems theory (STS) is widely used in many forms of IS research—for example, as a basis for Checkland's software systems methodology (Checkland, 2000).

Without going too deeply into this debate, we acknowledge the relevance of GST and STS to DSR by recognizing that DSR projects address real-world, wicked problems involving the design of complex information systems (Rittel & Webber, 1984). Complex systems combine human and technology components, the functional and quality attributes of which are not necessarily known separately or as an integrated whole. The general, sociotechnical nature of these systems means that a complete understanding of such systems is difficult or even impossible. The DSR project must somehow manage this complexity via the simultaneous construction of a problem space and a solution space, both of which grow in completeness while evolving through multiple DSR iterations (Gill & Hevner, 2013; Hevner, 2017).

Thus, while the requirements of GST as defined by Demetis & Lee (2016) are helpful for describing the complex system nature of the problem environment, they offer few insights into the design solutions needed to change and improve that environment. The DSR paradigm provides the essential problem solving steps (build and evaluate) and intervention activities (e.g. action design research) that support the creative designs needed to solve problems in the application environment and to grow the application knowledge bases. Thus, we posit that GST and STS are useful for describing the complexities of the problem space, while DSR is essential for building and evaluating effective system designs in the solution space—which can be then further analyzed, for example, through an STS lens.

4 Design Artifacts

The information technology (IT) artifact should be a focal point in most IS research. The study of information technology and systems in various socioeconomic contexts is predicated on a deep knowledge of the artifacts in use. In their insightful essay, Orlikowski and Iacono (2001) argue that while the IT artifact is the core subject matter of IS research, it is too often taken for granted and treated as a passive black box for study. They challenge the IS community to engage more deeply and seriously with the "multiple, emergent, and dynamic properties" of the IT artifact.

In order to make a better world (Walsham, 2012), the goal of DSR is to invent new artifacts where none exist and to improve existing artifacts to enhance organizational, group, and individual human productivities and effectiveness. A primary rationale for the DSR paradigm is to establish rigorous ground rules for growing knowledge contributions around building and evaluating the IT artifact (Hevner et al., 2004).

An IT artifact can be categorized as a construct, model, method, or instantiation (March & Smith, 1995). Constructs define the basic concepts and language in which problems and solutions are defined and communicated. Models use constructs to represent the real-world contexts of the design problem and solution spaces. Methods define processes, such as solution algorithms. Instantiations show that constructs, models, and methods can be implemented in a working system; they demonstrate feasibility, enabling concrete assessment of an artifact's suitability for its intended purpose. They also enable researchers to learn about the real world, how the artifact affects it, and how users appropriate the design artifact in a real-world context.

Gregor and Hevner (2013) describe the different types of IT artifacts at varying abstraction levels of knowledge contribution based upon the maturities of the problem (i.e., application) domain and the solution domain. Thus, a particular DSR research project can produce novel artifacts on one or more of three levels, ranging from specific instantiations in the form of products and processes (level 1), to more general (i.e., abstract) contributions in the form of nascent design theory (e.g., constructs, design principles, models, and technological rules; level 2), to well-developed mid-range design theories about the phenomena under study (level 3). Note that a situated implementation (level 1) can be considered a sufficient knowledge contribution even in the absence of further abstraction or theorizing about its design principles.

Demonstration of a novel IT artifact instantiation can be a research contribution that embodies design ideas and theories yet to be articulated, formalized, and fully understood. Novel design artifacts present a particular challenge to traditional IS research. The creative process through which they are envisioned may not meet the criteria of usefulness and rigor suggested by the original guidelines and the potential benefits of the design may be hard to evaluate. A genuinely new invention is a difficult goal for DSR research projects and we can expect few research contributions to be true inventions (Gregor & Hevner, 2013). However, we should encourage the exploration of new ideas and artifacts regardless of the hurdles.

Thus, it can be strongly argued and defended that design of the IT artifact precedes the development of nascent design theories as a natural sequence of activities in a DSR project. While both activities are important, building and evaluating the artifact often comes first. Once the IT artifact is realized and evaluated in context, then the researchers have time to reflect and generate design principles for broader impacts of the embedded artifact knowledge to a wider range of applications.

5 Design Theories

In addition to artifact design, *design theorizing* is an expected norm for DSR. This is not to say that a fully formed theory is expected in any one single project or article, but there should be some reflection on the advance in *design knowledge* that is being made. Design knowledge is seen as ranging from knowledge that is implicitly represented in the descriptions of the form and functions of an artifact, to nascent design theory such as design principles, to well-developed design theory.

The emphasis is on "design" because it is the contribution to design knowledge and theory that should be the primary criterion for assessing contributions in DSR, not contributions to other forms of nondesign theory. That is, using the theory categories in Gregor (2006), we look for prescriptive type 5 theory (theory for design and action), and not necessarily types 1 to 4 that involve descriptive, "nondesign" theory. Personal experiences suggest, however, that it is the preference for conventional nondesign theory that leads to the familiar justification for rejection in a review process: "Where's the theory?" New design knowledge is not seen as a sufficient contribution for publication, and framing against a contribution to social science or behavioral theories is deemed required. DSR will not reach its full potential until IS can move beyond its historical preoccupation with nondesign theory.

The focus on DSR as a research paradigm has a relatively short history and it is perhaps not surprising that views on theorizing in DSR are still evolving. However, interest in design theorizing as a process does appear to be growing. Gregor and Hevner (2013) attempt to dispel the perception that there are two "camps" in DSR—a design theory camp and an artifact camp. Their article shows how contributions to knowledge in DSR could be justified in terms of advances in knowledge in either a problem or a solution domain. Design theory development may occur over time and over multiple projects, with small steps and revisions on an ongoing basis.

Gregor (2009) argues that a special framework is needed for thinking about theorizing in DSR to clearly distinguish it from other types of science. Further work on design theorizing processes has followed in Fischer and Gregor (2011), Fischer, Gregor and Aier (2012), Lee, Pries-Heje, and Baskerville (2011), and Gregor and Hevner (2013). The design-centric theorizing framework in Figure 2 shows two general modes of DSR activity and theorizing (see also Simon, 1996). The interior mode in the design-centric framework is where theorizing is done to produce theory for design and action, with prescriptive statements about how artifacts can be designed, implemented, and evaluated. The exterior mode aims at analyzing, describing, and predicting what happens as artifacts exist and are used in their external environments. The theorizing that occurs in the external mode is still design-oriented theorizing even though it is not producing artifacts and is perhaps not recognized as conventional DSR. It differs from traditional nondesign theorizing because it recognizes a special feature of artifacts, namely their goal-directedness, and focuses on design features that can be manipulated in the achievement of goals. Fischer (2011) in an analysis of DSR calls this "micro design research."

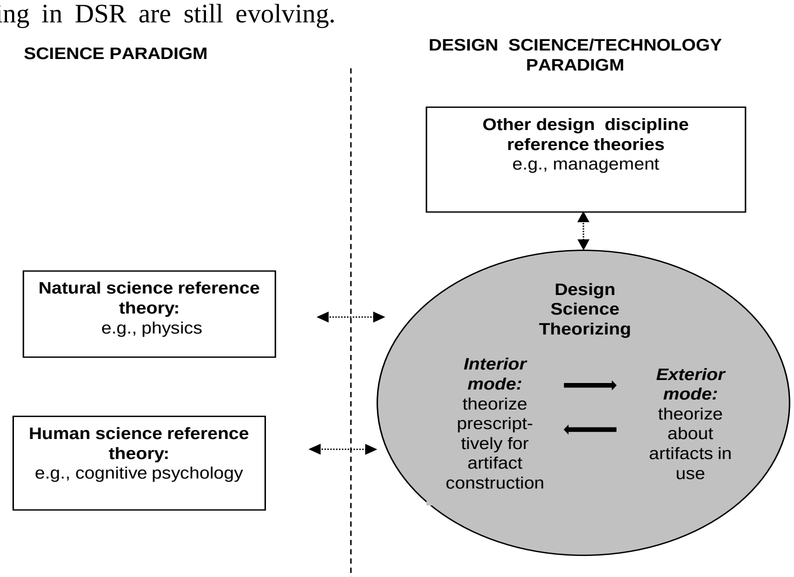

Figure 2: A Framework for the Centrality of Design Theorizing (adapted from Gregor, 2009)

In shorter-term cycles, artifact construction is not always dependent on any underlying nondesign knowledge. Methods for building and evaluating artifacts can develop over time through processes of trial and error, long before there is a deep understanding of relevant nondesign knowledge. For example, processes for developing iron and bronze occurred at early stages in human history and preceded the in-depth knowledge that was later developed in the science of chemistry. Other examples show that new artifacts can result from "eureka" moments where an inventor has a sudden flash of inspiration (Hughes, 2004). Simon (1996) gives further examples such as the first time-sharing computer that had only fragments of theory to guide its design and to predict how it would behave in an environment of users with differing demands.

In his book on the nature of technology, Arthur (2009) writes that technology creates itself collectively, and that technologies must come into being as "fresh combinations of what already exists" (p. 19). However, he also acknowledges the "considerable part human beings, in particular their minds, play in this combination process; new technologies are constructed mentally before they are constructed physically" (p. 23). The point here is that design knowledge is not derivable in any simple or direct manner from nondesign knowledge. If this were the case, there would be no need for trial and error processes or flashes of creative insights to develop new artifacts, and there would be no need for navigating through search spaces to find solutions to problems. Given their importance in facilitating technological and societal development, hard-won design knowledge and theory should be valued in and of themselves.

A second important aspect of the design-centric framework in Figure 2 is that DSR need not necessarily contribute to knowledge in the human and physical sciences, especially in the short-term. Study of the use of artifacts may, over time, lead to new insights into human behavior or the physical sciences, but this is not necessarily the concern of DSR projects, where the value lies in the prescriptive knowledge that is produced.

An appendix, at the end of this editorial, shows how the design-centric theorizing framework applies to research progress in the history of research in decision support systems (DSS).

To recap, design theorizing should be the expected norm for DSR even if the DSR project is presented as only one step in an overall research process; yet that step can be justified as a worthwhile advance in knowledge. A description of a new and novel artifact is sufficient if its newness and novelty can be justified in comparison with prior work. The distinctive nature and value of design knowledge should be recognized. There should not necessarily be a requirement to show that the DSR is based on theory in the natural and social sciences as new designs may arise by processes including trial-and-error and creative insights, rather than logical deduction from prior theory. Similarly, DSR should not be required to contribute to natural or social sciences as a primary aim; rather, the study of artifacts in use should be primarily aimed at progressing knowledge of artifacts, instead of human nature or natural objects.

6 DSR Processes

Methodologically, DSR originated as a science of the artificial (Simon, 1996). As applied in IS, DSR methods have grown distinct from the building approaches of computer science and from behavioral science approaches based on the natural sciences. First attempts at creating a methodical approach to DSR can be traced to Nunamaker et al. (1991) who proposed systems development as a viable research strategy in IS research. Their approach is seen as a valuable first step, but can be critiqued for its lack of clear theoretical or scientific outputs. To address this problem Walls et al. (1992) and March and Smith (1995) propose the use of kernel theories in theory testing and building in constructive research. Markus et al. (2002) provide a concrete design and a theory that has since been used as an exemplar for design methods. Hevner et al. (2004) define a set of principles for canonical design research. This paper led to a proliferation of both articles describing individual DSR projects and articles dealing with the DSR process. Peffers, Tuunanen, Rothenberger, & Chatterjee (2008) propose a method and a process outline for performing DSR, and Kuechler and Vaishnavi (2008), drawing from Takeda, Veerkamp, Tomiyama, & Yoshikawam, (1990), propose a high level design process, which they claim nearly all DSR methods follow with only slight variations in details (see Figure 3). These papers present a codified process and propose ways for developing an artifact in a rigorous manner and reporting the results.

The next phase in the development of the DSR approach was the introduction of a more explicit practical contribution orientation through introducing action research cycles—or design interventions—into the process (Sein et al., 2011). This action design research (ADR) approach added more reflection and potential practical relevance to the DSR process. However, we note that these methodical approaches alone do not dictate what the expected DSR outputs are. They simply provide key guidelines for planning, reporting, and evaluating DSR projects (e.g., the DSR presentation template in Gregor & Hevner (2013)).

The reporting and evaluation guidelines in different DSR methods emphasize in various degrees the rigor of theorizing or the relevance for practitioners. Thus the evaluation of practical utility is either done through cases or laboratory trials (Nunamaker et al., 1991), or more recently, increasingly through analyzing the feasibility of the IT artifact after deployment in the organization (e.g., Sein et al., 2011). The proposed artifact should resolve the problem situation of the clients in a satisfactory manner while satisfying the criteria for being a DSR knowledge contribution. The artifact can be evaluated against internal criteria, which assess (1) the degree of match between the artifact and any kernel theories that were theorized to be ingrained in it, and (2) the degree of match with the generally accepted principles of designed artifacts (or the expected product in marketing parlance). Measures of utility provide evidence for practical contributions; for example, Kasanen, Lukka and Siitonen's (1993) weak and strong market test (e.g., the client organization that continues to use the artifact or the design wins a notable market share). At the same time, the contribution to design theory should be evaluated so that it confirms or challenges the chosen theoretical position or the theory ingrained in the artifact (Rossi, Henfridsson, Lyytinen, & Siau, 2013).

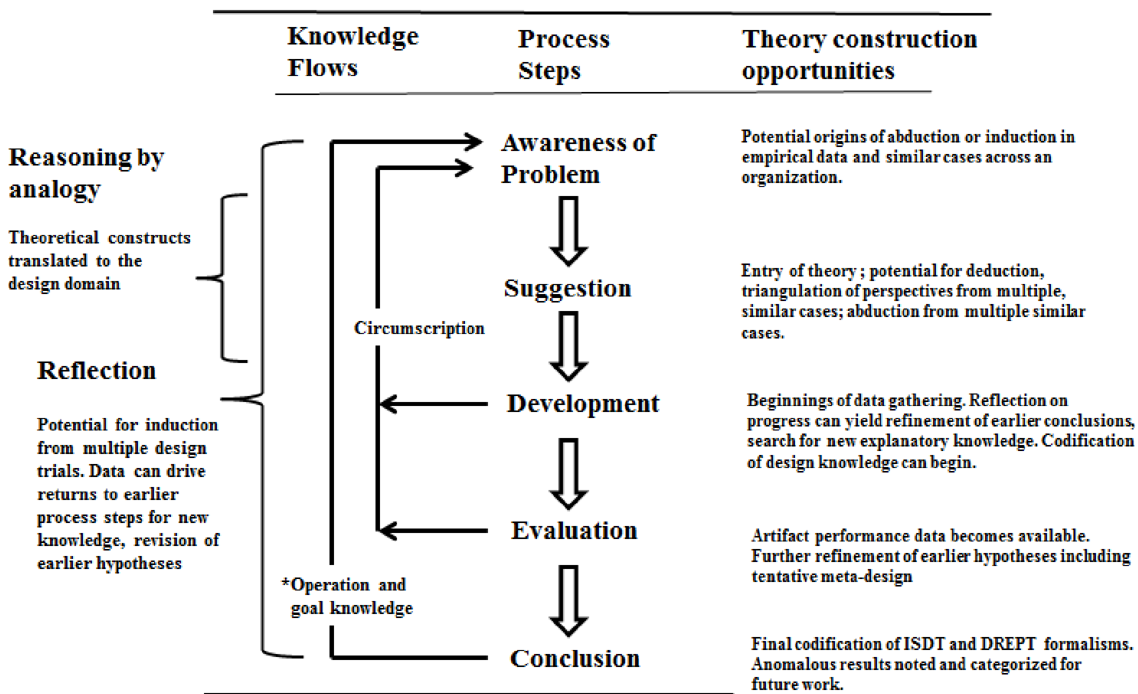

Figure 2. High Level Design Research Process (adapted from Kuechler & Vaishnavi 2008)

As Cross (2001, p. 53) notes, "the study of the principles, practices, and procedures of design", is an important part of the science of design. In IS research, however, this aspect has received less attention, especially after the large-scale systems development methods and method engineering approaches fell out of fashion. However, some of the key possible outcomes of DSR projects are design principles (or rules), which are often formulated so that they deal with the principles or procedures of design. Such outcomes of design research should be of value, especially for practitioners, and even studies of failed design processes can yield valuable outcomes. Thus, we believe that it is important for DSR projects to reflect on their processes and to identify potential process improvements as research contributions to the IS community.

7 DSR Impacts

The concept of impact regards the effect, influence, or impression made by one thing upon the other (OED, 2016). The "one thing" in our case is DSR. The "other" in our case is primarily information systems research and practice. However, each of these things has multiple dimensions. For the "one thing" in our case, Table 1 enumerates at least five objectives available in DSR. Of particular interest in relation to impacts is the distinctive contrast between the objectives of design artifacts and those of design theory. For the "other thing" in our case, the notion of rigor *and* relevance in DSR suggests that it should encompass two kinds of impact. DSR should impact practice *and* DSR should impact research. Design theory should impact research and practice. Design artifacts should impact research and practice. We might build a simplistic expectation of an alignment: i.e., design artifacts impact practice, while design theories impact research. Although there indeed may be some prevalence of either artifact or theory present in such an impact alignment, both design artifacts and design theory each have potential practical and research impacts, even if indirectly. We briefly explore the impacts of DSR theories and artifacts on both practice and research.

7.1 Practical Impacts

Most commonly, the design artifact is the prevalent objective leading to practical impacts. It has been more than ten years since Agarwal and Lucas (2005) called for more attention on the transformational impact of IT artifacts. At that time, they delineated five kinds of impacts (p. 393):

- "dramatically alters cost structures and provides new opportunities for revenue."
- "provides new levels of customer service and convenience."
- "compels organizations to continually reassess and realign their strategies in response to changes in technology."
- "creates new industries and innovative forms of business, which generate positive economic activity."
- "enriches people's lives. From a welfare standpoint, people who have access to this technology are better off."

In addition, mobile, social networking, Internet-of-things, and data analytic technologies would (at least) elaborate this list to include:

- provides fundamental mechanisms by which people communicate and interact.
- delivers media for creating and maintaining broad forms of global communities.
- collects and analyzes data to generate new opportunities for all levels of decision-making.
- systematically protects the environment and enhances sustainability through ecological efficiency, equity, and effectiveness.

There are certainly other kinds of impacts yet unmentioned that would belong to such a list. There is an increasingly wide range of human domains that new IT artifacts might impact. From a systems perspective, the impacts in these lists affect ever more complex systems and combine with other artifacts to construct increasingly complex artifacts (Demetis & Lee, 2016, 2017). An IT artifact might have interior impacts or exterior impacts or both. Interior impacts include the impact of the DSR on the system of artifact(s) being produced in the research. At its simplest level, DSR may result in the creation and evaluation of a new kind of technical artifact—e.g., a new kind of data search algorithm. DSR would certainly impact such an artifact by creating it. But the scope of the interior effects is likely to be dependent on the goal of the research, the problem being addressed. If the problem is broader than just a data search algorithm—say the need to make a data analytics organization more efficient—then this algorithm may be the critical element in the solution to the organizational efficiency problem. This technical artifact might be incorporated into a previously existing data analytics system in order to make the system search large blocks of data faster. The algorithm revises this system to make it more complete and more efficient in serving its purpose. With the addition of the algorithm, it is effectively a "new" system: a "new" artifact.

In this way, there are at least two artifacts resulting from the DSR: the new algorithm and the revised system. The system may be more complex, and indeed made even more complex by the additional algorithm. In fact, the revised system now makes the organization more efficient, which is the original goal of the project. So there are at least three artifacts produced in this case: the new algorithm, the revised system, and the more efficient organization. All three of these artifacts are effectively created (or recreated) by the DSR project. The interior impacts can operate at several levels in terms of the complexity of the systems impacted.

Why not go further? Perhaps the more efficient organization makes for a more efficient market. Perhaps the more efficient market makes for a more efficient economy. In this case, we go no further than the more efficient organization because this level of artifact was defined as the goal of the project. The interior DSR impacts can involve cascading effects of more fundamental artifacts that systematically combine with other elements in larger, enveloping systems. Similarly to an "agential cut" (Shultze, 2017), we conceptually cut this cascade according to the originally stated goals of the DSR. The interior impacts are found among the artifacts being created to achieve the stated goals arising in the definition of the problem. The exterior impacts take over from there.

Exterior impacts primarily regard the broader realms of information systems research and practice, those beyond the defined goals for the solution to the problem. In the example, such exterior impacts could be those on the market or the economy.

For the artifact itself to be worthy, it should be effective. This effectiveness should be of a sufficient size to compel an acknowledgement of its ability to solve design problems. Where design problems are common, this acknowledgment would motivate the dissemination of the artifact. Like many other forms of research that practice values, the artifact should have an appreciable *effect size*. Even when nonstandardized, "effect-size measures capture the level or change in the outcome variable in original units (e.g., change in number of successful start-up firms, fraction of retained employees)" (Schwab, 2015, p. 722).

Fortunately, most DSR projects engage in an explicit evaluation step. Such evaluations will at least provide a summative report of the effect size of IT artifact impacts (Venable, Pries-Heje & Baskerville, 2016). By tying the evaluation outcome variables back to the design goals, an impact effect size can be developed. For example, if the goal of an IT artifact is to improve password quality, then the effect size might be measured as the percentage increase in password length, the increased frequency of symbols in passwords, etc.

The design artifact's effects on research results are of obvious importance when they provide confirmation of the underlying design theory. But the artifact's effects can be even more important when they exceed or conflict with that theory. These effects can exceed the theory when the artifact delivers not only the effects prescribed in the design theory, but also further effects that are surprising. The effects can conflict with the theory when the prescribed effects fail to materialize. Either result can trigger further design theorizing. Some of the most astonishing scientific discoveries have arisen from unexpected results in the practical outcomes when theory is applied (Root-Bernstein, 1989).

7.2 Research Impacts

Most commonly, design theory is the prevalent objective grounding DSR research impacts. Earlier, we asked: "Must a DSR research project produce both artifact **and** theory?" By definition, a resulting DSR artifact implies the existence of some form of design theory, even if it is left implicit. In today's world of academia, the importance of *impact*, as a measure of research quality, is growing. This measure is most prevalent in the form of *impact factors*, which denote citation rates (the number of times certain scholarly articles have been cited by other scholarly articles). Accordingly, we are free to regard one measure of the impact of a theory as the frequency of citations to an article that primarily communicates that theory. While there are many possible confounds to such a simple measure, it does basically reflect how the ideas found in a design theory have influenced or impressed other researchers. Citation rates suggest that a theory has not only disseminated, but has been found useful. Indeed, impact is more traditionally measured by dissemination alone. Acceptance and publication alone, in selective peer-reviewed journals, of works that report theory may often be regarded as a sufficient indicator of the quality of the work. Such journals may themselves be high in impact, as indicated by their impact factors. A further measure of theory impact might be derived from the subscriber numbers or readership of the publication, or more directly, from the number of times the specific article has been downloaded. Reprint numbers are yet another indicator of readership interest.

But all of the measures above are substitutes. They imply that the theory has affected, influenced, or made an impression on other people, other things (e.g., artifacts), and particularly, other theories. In science, the contribution of most theories lies in raising the possibility of further contributions (leading to the impact factor measures above). DSR and its design theories are no different. This kind of theoretical contribution is represented by the twelfth-century adage that each contributor stands on the shoulders of giants. By so standing, one can see farther on the horizon than the giants beneath (Eco, 2006)

However, the research impacts of design theory objectives are difficult to isolate from the research impacts of design artifacts. Does the artifact have a lead role as a research outcome on its own? In information systems, the impact of design artifacts is quite another thing altogether. In the context of information systems, the impacts of artifacts are regarded as highly contextual: "IT artifacts impact (and are impacted by) the contexts in which they are embedded" (Benbasat & Zmud, 2003, p.186). Impact is the "(direct and indirect, intended and unintended) impact of these artifacts on the humans who directly (and indirectly) interact with them," plus the tasks, structures and contexts within which they are embedded, and the associated collectives (groups, work units, organizations, and industries) (Benbasat & Zmud, 2003, p.186), as elaborated by Agarwal and Lucas (2005). Such definitions convey a sense in the field of information systems that the impact of artifacts will usually regard a specific, unique situation, setting, or context. It is an idiographic impact that will vary from setting to setting. In contrast, there seems to be a sense that the impact of theory will mainly regard a more general field of usage—it is a broader and more universal impact.

In engineering and computer science, artifacts are generally regarded as more universal. Artifacts are another vehicle for the dissemination of knowledge. When artifacts have great impact, they affect many manufactured products, as a software product is massively downloaded, for example. The *idea* that is embodied by the artifact disseminates along with the artifact. Many regard the dissemination of an artifact as an important form of knowledge dissemination that is equivalent to dissemination by publication (Committee on Academic Careers for Experimental Computer Scientists, 1994).

From this perspective, the theory that underlies a design artifact is embodied by that artifact. The design artifact encodes its design theory. Kurt Lewin's comment that *there is nothing as practical as a good theory* is often cited (Stam, 1996). This conflation of design artifact and design theory opens the possibility of not only reverse engineering the artifact, but reverse designing the artifact. Reverse engineering is the well-known "practice of deciphering designs from finished products" (Chikofsky & Cross, 1990, p. 13). A product is disassembled to reveal how it works, usually for the purpose of learning how to duplicate, maintain, or modify its functionality. Likewise, *reverse designing*, known also as *design recovery* "recreates design abstractions from a combination of code, existing design documentation (if available), personal experience, and general knowledge about problem and application domains" (Biggerstaff, 1989, p.36). Depending on personal experience, reverse designing may yield even higher-level abstractions like the design theory that underlies the design artifact.

In the way that impact unfolds, the artifact and the theory are distinctive. The impacts are both cumulative and cohesive. However, the outcome of this impact may, in some cases, not distinguish the impact-of-the-design-theory from the impact-of-the-design-artifact. These are two sides of the same coin. The outcome of each impact may be inseparable from its companion.

8 Conclusions and a Call to Action

The goal of this editorial is to clarify the balance needed for the technical and scientific contributions of a DSR project. Our thinking follows five positioning perspectives:

- Science and technology evolution: A DSR project must understand and correctly position itself in the science-technology dualism of interactive cycles. Within the application domain, researchers must reference and apply the appropriate knowledge bases of scientific (descriptive) knowledge and technical (prescriptive) knowledge. Contributions to both technology (artifacts) and science (theories) are made as appropriate to the goals of the research project.
- Design artifact: In most DSR projects, the artifact precedes the development of nascent design theories in a natural sequence of events. While both activities are important, building and evaluating the artifact in the solution of a real-world problem or opportunity typically comes first.
- Design theories: It is argued that some degree of design theorizing should be expected in DSR. The description of a new and novel artifact can make a contribution to design knowledge and its initial conceptualization is a first step in theorizing. It should be understood that new artifacts and design knowledge may arise from creative insights and trial-and-error processes and therefore do not need to have a close deductive relationship with existing scientific knowledge (kernel theories). Neither is it necessary to make a contribution to descriptive (i.e., nondesign) theories in a specific project.
- DSR processes: A methodical approach to DSR provides a guiding foundation for the rigorous execution of the research with some assurance that impactful results will come out of the effort. Researchers should select and follow a suitable method, given their entry point to the research and their expected contributions. Improvements to the DSR process should also be considered as research contributions.
- DSR impacts: The IT artifact is a vehicle for research and practice impacts. These impacts can include both the practical impact of the designed artifact and the research impact of the design theory embedded in the artifact. Evidence of how these vehicles may have affected future work can be found in the practical outcome effect size of the artifact, and in the citation counts of scholarly and practical references to publications about the practical and research outcomes. The breadth of distribution of the artifacts that proceed from the research outcomes can also serve as evidence. Just as theories can be practical, design artifacts can also embed the theoretical.

The five perspectives presented are complementary and demonstrate that artifact construction and design theorizing are necessary and interrelated aspects of DSR. Table 1 briefly summarizes the positioning and guidance provided by these different perspectives. In conclusion, we call for action to produce more rigorous and relevant DSR research projects and highly visible publications in the IS field. This editorial's important take-away is that excellent DSR can contribute through novel artifacts, as well as, generalizable design theories to the application knowledge bases of the world. The decision to publish DSR in IS journals must effectively judge the research project's artifacts, design theories, processes, and future impacts as the bases for acceptance rather than solely relying on ingrained biases for descriptive theory contributions. The following insights support our call for action:

- A contribution to design (prescriptive, technological) knowledge can be recognized as a *sufficient* contribution when the newness and usefulness of an artifact can be demonstrated, although there may be limited conceptualization and theorizing. This is especially true in early stages of a DSR project, when a novel artifact is being envisioned and built.

- Design theory (prescriptive, scientific knowledge) is a *desirable* goal as theorizing around a class of artifacts progresses. A development of design theory supports the longitudinal goals of DSR research for continuous improvement of the application design context and growth of the design knowledge bases.
- DSR projects are typically longitudinal streams of research. Varied contributions will appear at different points along the research stream. Researchers must identify the appropriate times to present and publish the research contributions in terms of the *continually* evolving artifacts and design theories.
- The relationship between descriptive knowledge from kernel theory and the development of new artifacts demands greater attention in DSR. The artifact precedence perspective posits that artifacts come first and that knowledge flows between technology and science occur over long periods. The design theory centrality perspective argues strongly that artifacts can be constructed *without requiring* a kernel theory as a source. This view is compatible with views that Simon (1996) expresses strongly in what he terms the "skyhook-skyscraper" (p. 16) construction of science, where parts of a system are modeled at a high level before details of the lower level are understood.

To summarize, we believe that DSR contributions form a continuum on at least two dimensions: from very novel artifacts to rigorous theory development and from early visions of technology impact to studies of technology impact on users, organizations and society. There can thus be multiple types of published contributions depending on the novelty of the artifact and the phase of the research project. As scientific research is expected to contribute to the society positively, it is our task to write and publish studies of the impact of innovations on society at large. This aligns with our call for greater relevance of IS research and emphasizes the important role of DSR in the overall vision of IS research.

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Appendix: The Design Centric Framework and Some History in Decision Support Systems Research

DESIGN SCIENCE/TECHNOLOGY PARADIGM

Design Science Theorizing—Interior Mode: in which theorizing is done prescriptively for artifact construction

The original concept of decision support systems (DSS) is attributed to a creative association of ideas of Scott Morton in 1964. Scott Morton's (1967) dissertation "was seen as a pioneering implementation, definition and research test of a model-driven Decision Support System" (Power, 2003). "The concept of decision support evolved from the theoretical studies of organizational decision making done at the Carnegie Institute of Technology during the late 1950s and early '60s and the technical work on the interactive computer systems, mainly carried out at the Massachusetts Institute of Technology in the 1960s" (Power, 2004, p. 2026). Note that although the early work on DSS was informed by theorizing from other design disciplines (e.g., Simon's model of management decision making and early work on interactive information technology), it did not derive in any directly deductive sense from the canons of this theory. In fact, Scott Morton (2007) reflected that part of his motivation was his reaction to the conventional wisdom of a management professor with whom he disagreed: "that managers cannot/will not/should not ever use computers or computer terminals for any management purpose whatsoever."

Work in the interior design mode on DSS continued. Little (1970) in an article in *Management Science* identified what would now be termed design principles for DSS: For example, a model used by managers should be complete, including important phenomena even if they require judgmental estimates of their effect. Little's article and principles were based on practical experience rather than existing management theory, and he points out problems with the tendency of professional operations research and management science scholars to escalate model building into complexity.

Design Science Theorizing—Exterior Mode: in which theorizing is done about artifacts in use

Work was also done relatively early on the use of DSS in use. Alavi (1982) studied executives' perceptions of DSS concepts and their needs and desired benefits related to DSS. From a series of in-depth interviews she identified design principles relating both to the DSS product (e.g., "the DSS should provide capabilities for complexity coping, conflict resolution and uncertainty reduction"). She also provided principles relating to the processes of DSS development (e.g., "if possible, a prototype should be built before developing the full-scale system" (p. 1). Thus, work in the exterior mode in the design science paradigm can also contribute to design knowledge.

Role of Other Design Discipline Reference Theories: e.g., management

Early DSS drew on emerging knowledge in other design disciplines, in terms of theories of managerial decision making and knowledge of information technology capabilities, as shown in the early work by Scott Morton on DSS. However, the knowledge from other areas was not applied uncritically, and the importance of developing artifact knowledge and theory through design science processes is evident. For example, Sprague (1980, p. 6) refers to a police beat allocation system used in California that was able to "amplify a manager's judgement." He notes that a later experiment that applied a traditional linear programming model to the problem yielded a less satisfactory solution than the one designed by a police officer.

SCIENCE PARADIGM

Natural Science Reference Theories

Little or no evidence can be found in the history of DSS development of the use of theory from the natural sciences.

Human Science Reference Theories

Evidence can be found of studies that investigate the use of DSS and rely on theories relating to human behavior as a lens, rather than artifact design. Alavi and Joachimsthaler (1992) performed a meta-analysis of DSS studies with the aim of providing guidelines for implementation management and conduct of future research. Their focus was on "four sets of user-related factors believed to influence DSS implementation success: cognitive style, personality, demographics, and user-situational variables" (p. 96). Although the study did give some guidance to designers, including that user involvement in the development of DSS was found to be important, the nature of the DSS artifact was largely treated as a "black box." No specific guidelines are given as to how user involvement is to be arranged: that is, there is no detailed prescriptive knowledge.

A Final Note: The Distinctive Value of Design Knowledge in DSS

This illustration is provided with the aim of showing the distinctiveness of design knowledge in DSS, a major strand of research in information systems and one that deals with sociotechnical systems, rather than the purely technical systems found in some closely associated fields such as computer science. The design knowledge yielded for DSS, whether as design principles, design theory, or as implicitly shown in artifacts, is distinctive in that it is prescriptive rather than descriptive as in the science paradigm. Design knowledge is also shown to be distinctive, in that seminal DSS work (e.g., Little, 1970) was not derived from reference or kernel theories from the human (behavioral) sciences, but was developed from practical work and experimentation. The prescriptive knowledge and theory emanating from DSR should be recognized for its unique value and its importance for the field. Would the article by Little be accepted in a major journal today? It should be, if the arguments for the distinctive value of design knowledge are accepted.

Note that similar conclusions have been drawn outside of this brief illustration. A critical analysis of DSS research notes says that much of the early work on DSS was radical and highly experimental. This analysis also concluded that design science (the interior mode) is a major DSS research category (Arnott & Pervan, 2005).

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