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 19th 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 *Encyclopdie* (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 Ω 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 Ω 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 Ω 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 Ω "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 Ω and Λ 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 Λ 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 Λ 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 Ω and Λ. Consider the scenario illustrated in Figure B1. Initial investigation of an exciting research question may find little available Ω 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 Ω and Λ. 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 Λ and the initial empirical evaluation results in Ω. As these artifacts are employed in the application environment over time, additional behavioral research studies may be performed to increase the Ω knowledge of their use.

At some point, design cycle 2 will begin from a new Ω 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 Λ 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 Λ and new propositional knowledge to Ω. 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.
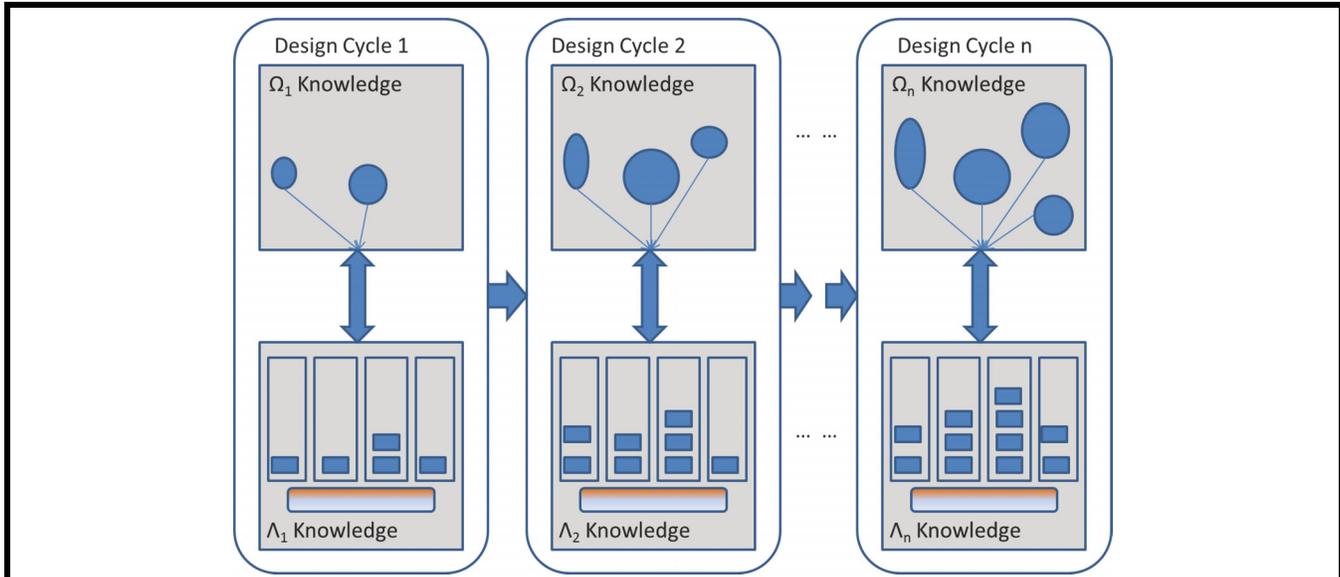
Figure B1. Evolution of Knowledge via Design Cycles

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 mode'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.

References

Baskerville, R., Pries-Heje, J., and Venable, J. 2009. "Soft Design Science Methodology," in *Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology*, Malvern, PA, pp. 9-20.

Bunge, M. 1998. *Philosophy of Science, Volume 2: From Explanation to Justification*, New Brunswick, NJ: Transaction Publishers.

Christensen, C. 2000. *The Innovator's Dilemma*, New York: Harper Business.

Conant, J., Mokwa, M., and Varadarajan, P. 1990. "Strategic Types, Distinctive Marketing Competencies, and Organizational Performance: A Multiple Measures-Based Study," *Strategic Management Journal* (11:5), pp. 365-383.

Dubin, R. 1978. *Theory Building* (rev. ed.), New York, NY: The Free Press.

Eisenhardt, K. 1989. "Building Theories from Case Study Research," *Academy of Management Review* (14:4), pp. 532-550.

Gregor, S. 2006. "The Nature of Theory in Information Systems," *MIS Quarterly* (30:3), pp. 611-642.

Gregor, S., and Jones, D. 2007. "The Anatomy of a Design Theory," *Journal of the Association of Information Systems* (8:5), pp. 312-335.

Hempel, C. 1966. *Philosophy of Natural Science,* Englewood Cliffs, NJ: Prentice-Hall.

Hevner, A., March, S., Park, J., and Ram, S. (2004). "Design Science in Information Systems Research," *MIS Quarterly* (28:1), pp. 75-105.

March, S., and Smith, G. 1995. "Design and Natural Science Research on Information Technology," *Decision Support Systems* (15), pp. 251-266.

McLaren, T., Head, M., Yuan., Y., and Chan, Y. 2011. "A Multilevel Model for Measuring Fit between a Firm's Competitive Strategies and Information Systems Capabilities," *MIS Quarterly* (35:4), pp. 909-929.

Merton, R. 1968. *Social Theory and Social Structure* (enlarged ed.), New York: The Free Press.

Mokyr, J. 2002. *The Gifts of Athena: Historical Origins of the Knowledge Economy*, Princeton, NJ: Princeton University Press.

Nagel, E. 1979. *The Structure of Science Problems in the Logic of Scientific Explanation*, Indianapolis, IN: Hackett Publishing Co.

Parry, R. 2008. "Episteme and Techne," in *The Stanford Encyclopedia of Philosophy* (Fall 2008 edition), E. N. Zalta (ed.), Metaphysics Research Lab, CSLI, Stanford University (http:// plato.stanford.edu/archives/fall2008/entries/episteme-techne/).

Simon, H. 1996. *The Sciences of the Artificial* (3rd ed)., Cambridge, MA: MIT Press.

Walls, J., Widemeyer, G., and El Sawy, O. 1992. "Building an Information System Design Theory for Vigilant EIS," *Information Systems Research* (3:1), pp. 36-59.

Weber, R. 2012. "Evaluating and Developing Theories in the Information Systems Discipline," *Journal of the Association for Information Systems* (13:1), pp. 1-30.