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The Sciences of Design: Observations on an Emerging Field

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Abstract

The boundaries and contours of design sciences continue to undergo definition and refinement. In many ways, the sciences of design defy disciplinary characterization. They demand multiple epistemologies, theoretical orientations (e.g. construction, analysis or intervention) and value considerations. As our understanding of this emerging field of study grows, we become aware that the sciences of design require a systemic perspective that spans disciplinary boundaries. The Doctoral Consortium at the Design Science Research Conference in Information Sciences and Technology (DESRIST) was an important milepost in their evolution. It provided a forum where students and leading researchers in the design sciences challenged one another to tackle topics and concerns that are similar across different disciplines. This paper reports on the consortium outcomes and insights from mentors who took part in it. We develop a set of observations to guide the evolution of the sciences of design. It is our intent that the observations will be beneficial, not only for IS researchers, but also for colleagues in allied disciplines who are already contributing to shaping the sciences of design.

KEYWORDS: Design research, sciences of design, design as science, discipline, body of knowledge, system of professions

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The Sciences of Design: Observations on an Emerging Field

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I. INTRODUCTION

The sciences of design are a relatively new entrant to the set of methodologies, paradigms and orientations that have been dominated by debates previously only positioned as positivist versus interpretive and quantitative versus qualitative. Although this change is visible in the IS discipline only since the mid-1990s, design has been recognized and practiced as an important mode of research in other professional disciplines such as architecture [Cross et al. 1997; Cross 2007] and engineering [Suh 1990; Suh 2001]. The importance of sciences of design was recognized by seminal publications aimed at the (then) new computing sciences, such as Simon's Sciences of the Artificial [Simon 1969]; recognition of the notion of a "design theory" [Walls et al. 1992]; articulation of a "systems development methodology" for research [Nunamaker et al. 1991]; and the first articulation of design science for the technology-oriented subgroup of researchers within the IS community by March and Smith [1995]. In 2004, design science research was highlighted as a clear alternative by Hevner et al. [2004]. Since that publication, applications, variations, and extensions have continued to appear that investigate the importance of design and design science in information technology and organizations. Notable among these are papers that describe the anatomy of a design theory [Gregor and Jones 2007], arguments about the nature of artifacts and artifact mutability [Ivari 2003], and research directed at what is referred to as positive design and appreciative inquiry [Avital et al. 2008]. On the technology front, efforts to understand the sciences of design have resulted in elaboration of patterns [Vaishnavi and Kuechler 2008], investigation of the use of theories in design science [Purao 2002], cross-fertilization with related approaches such as action research [Cole et al. 2005; Rossi and Sein 2003], and examination of design science from a critical realist perspective [Carlsson 2005]. In addition to Cross, et al. [1997] Simon [1969], and Nam Suh [2001], the mileposts above are drawn from the Information Systems discipline in an effort to trace, albeit in a sketchy manner, the rapid recognition and evolution of the sciences of design within the discipline, which is further underscored by the publication of a special issue of MIS Quarterly devoted to design science [March and Storey 2008].

Seen in the larger context of a system of disciplines and fields of knowledge, this rise of design sciences requires recognition of disturbances that are external to the IS discipline. They may be characterized as the need for prescriptive (as opposed to descriptive) approaches because of the explosive growth of information technologies, the need for multi- and trans-disciplinary approaches to solving important societal problems [COSEPUP 2004], and signals from other disciplines. Abbott [1988] provides a cogent model of the "system of professions" (following a systems-theoretic perspective), where he links the idea of a 'profession' to a specific type of 'work.' Seen in this manner, the professions (and, as a consequence, the resulting disciplines) follow interrelated evolution trajectories. Abbott's model (further elaborated in Abbott [2001]) is useful because he goes beyond societal forces as the *external* influences, and differentiation and struggles within a discipline as *internal* influences. He emphasizes the interrelatedness *among* disciplines as a key source of influence on the development of a discipline. He builds the argument following the notion of jurisdiction: "Since jurisdiction is exclusive, professions constitute an interdependent system" [Abbott 1988, p. 86]. The argument suggests that a move by one discipline inevitably affects others. In other words, embracing and welcoming design science within the fold of approaches by the Information Systems discipline has consequences, both for its own internal structure, and for how it relates to other disciplines and their structure.

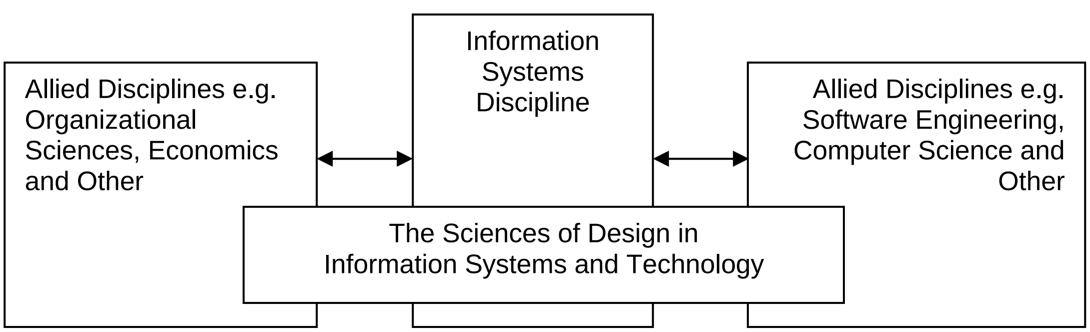

Figure 1. The Sciences of Design as an Evolution Affecting the System of Disciplines

The advance of *Design Science* within the Information Systems discipline may, then, be viewed as bridge-building with other disciplines that must necessarily contribute to the definition of its scope and methods and must participate in discussions about claims of jurisdiction on the body of knowledge. Continuing with the system of professions framework, we define a profession as a "somewhat exclusive group of individuals applying somewhat abstract knowledge to particular cases" [Abbott 1988, p. 318]. A key concern with this definition is the criteria used to define membership in this exclusive group of individuals. Given the nascent field of design sciences, the strategy must be "inclusive," while retaining an essential, fundamental or core related to the study of, research about, and performance of "design." The second concern, which will drive how the disciplines will engage in this debate, deals with the feasibility of the assertion that abstract knowledge is possible within the purview of design science. That is, design expertise and design knowledge can be separated from the domains in which design must occur. A significant portion of design knowledge, other than perhaps broad strategies such as divide-and-conquer, continues to be tied within disciplinary boundaries making the dialog across discipline difficult.

The Doctoral Consortium at the DESRIST Conference (Design Science in Information Systems and Technologies) was, therefore, a significant event in this emerging field of study. It attempted to seed discussions that were meant to progress beyond mere dialog across disciplinary boundaries. By bringing together seasoned researchers from a variety of disciplines, and reviewed submissions from doctoral candidates irrespective of discipline, the consortium tried to create an environment where some of the above issues could be discussed. The consortium attracted submissions from a large number of disciplines, each dealing with "Design as Research" or "Researching Design." The breadth of topics, domains, and techniques provided the impetus for discussions that culminated in several interesting perspectives. This report reflects on the consortium, describes experiences from mentors who took part in it, and synthesizes their perspectives. From this, a set of observations is put forward, with the intent that these observations will serve as guideposts in the evolution of this emerging field of study.

The paper is organized as follows. Section II positions the sciences of design as a field of study emphasizing its two significant strands "design as research" and "researching design" with a brief discussion of their evolution in related disciplines. In Section III, we describe the Doctoral Consortium itself, focusing on its participants and accomplishments. Section IV includes statements from mentors (both their a priori positions and their reflections on the Consortium). Section V develops several observations that synthesize the reflections from mentors, positioning each as both an opportunity and a challenge. Section VI concludes the paper by challenging the design science research community to create a body of knowledge, develop pedagogical techniques, and to build bridges with allied disciplines to realize the potential of this emerging field.

II. THE SCIENCES OF DESIGN AS AN EMERGING FIELD OF STUDY

Design Science Research, as outlined by Hevner et al. [2004], is quickly becoming an accepted mode of research within the IS discipline. Its boundaries and contours, however, remain fuzzy. A continuing source of uncertainty is the distinction, perceived or real, between "doing design" and "studying design" as the mode of research.[1] The first is exemplified within the IS discipline by Hevner et al. [2004]; the second is supported by the large body of work on study of design behaviors in a number of related disciplines [e.g. Cross et al. 1997]. The distinction between the two strands is evident and can be easily discerned in individual papers and projects. Instead of emphasizing the distinction, we prefer to advocate the position that their separation represents a false dichotomy. With increasing understanding of designer behaviors ("studying design"), one may argue that it becomes easier to mimic, automate, and even improve the processes of design ("doing design"). On the other hand, artifacts constructed via doing design can significantly impact design practices, which in turn can only be uncovered via studying design. Although each strand boasts of techniques that are likely to be uniquely differentiated compared to the other, this inherent interdependency makes their outcomes, if not their practice, complementary. In the following, we provide a brief overview of the two fields of study as a precursor to identifying the Doctoral Consortium at DESRIST as a marker in the evolution of this emerging field of study.

DESIGN AS RESEARCH

Design as Research encompasses the idea that doing design constitutes research. One might be hard-pressed to argue that early inventions were not research. Yet, some of these can be clearly pointed to as efforts at design. Consider, for example, artifacts such as eyeglasses, scissors or parachutes. Each contributed to our understanding of one or more phenomena, and allowed the harnessing of that understanding towards achieving a goal. An essential ingredient of this greater understanding was design, and the journey toward greater understanding was achieved as "knowing through building." The design research pages on ISWORLD [Vaishnavi 2008] from where the above examples are drawn, describe design as "creating something new that does not exist in nature." They emphasize, citing Simon [1996], that professions such as "architecture, business, education, law, and medicine, are all centrally concerned with the process of design," and that it is necessary to bring the design activity into focus at

[1] "Boland and Lyytinen [2003] suggest a different perspective: 'Research as Design' that re-conceptualizes the act of research itself as designing."

an intellectual level. Continuing with Simon's ideas, for information technologies, such design must construct an artifact that exists at the intersection between an outer (phenomenon) and inner (artifact) environments. Another important point of reference is the work by Carroll and Kellogg [1989] who describe artifacts as the nexus of multiple theoretical viewpoints. Examples of design science outcomes in this manner include tools to assist system designers [Batra and Davis 1992; Oxman 1994; Purao et al. 2003], methods for supporting and improving decision making [Dey and Sarkar 2000] and new ways of conceptualizing familiar phenomena such as information search [Storey et al. 2008]. The growth of knowledge, then, proceeds by accumulation of experiences and wisdom by observations or design and use of, and experiments that evaluate artifacts constructed via such design.

Knowledge generated via design can take several forms including constructs, models, methods and frameworks [March and Smith 1995], and may be articulated in the form of operational principles, defined as "any technique or frame of reference about a class of artifacts or its characteristics that facilitates creation, manipulation and modification of artifactual forms" [Dasgupta 1996]. Following Gregg et al. [2001], identification and understanding of the philosophical bases of design as research continue to be the subject of inquiry [Nieheves 2007]. A plausible contributor to this continuing work is the characterization of design by Bunge [1984] who implies that design research is most effective when its practitioners shift between pragmatic and critical realist perspectives, guided by a pragmatic assessment of progress in the design cycle. Purao [2002] presents an elaboration on the perspective shifts that accompany design research cycles to show that "the design researcher arrives at an interpretation (understanding) of the phenomenon and the design of the artifact simultaneously." The design as research mode, thus, provides an important strand of research that values research outcomes that focus on improvement of a phenomenon as the primary research concern, and seek understanding of the phenomenon as a secondary outcome via the process of designing.

RESEARCHING DESIGN

Researching Design (as opposed to Design as Research) shifts the focus to a study of designs and design processes. The community of researchers engaged in this mode of research is organized under the umbrella of the Design Research Society starting as early as the mid-1960s. Because of their focus on methods of designing, they have been able to articulate and follow the goal of generating domain-independent understanding of design processes although their investigations have been focused largely on architecture, engineering and product design. Although it is difficult to provide un-ambiguous and universally accepted definition of design process, working definitions suggest designs as plans, generating alternatives and selecting as well as the so-called wicked design where each level of design activity leads to additional puzzles [Rittell and Weber 1973]. Examples of work from this stream, therefore, include use of representations and languages [Oxman 1997], use of cognitive schemas [Goldschmidt 1994] and theoretical explorations [Love 2002]. An example in the IS discipline is the work by Purao et al [2003] who study how developers engage with problem and design spaces and interpret the findings drawing on work in other disciplines.

Although this field of study has focused on the study of design processes, pronouncements such as those by Archer [1979] portray a lean toward design as research: "There exists a 'designerly' way of thinking and communicating that is … as powerful as scientific and scholarly methods of enquiry" [Archer 1979]. Such "ways of knowing" come close to the notion of "knowing via building" identified earlier. The concepts of reflection and local knowing have also been articulated by Schön [1983], Nelson and Stolterman [2003], and extended by Mathiassen and Purao [2002] to emphasize reflection, local rationality, and knowing-in-action. Such partial overlaps indicate the affinity these two subfields of study are likely to have for each other.

AN EMERGING FIELD OF STUDY

Although we have tried to emphasize the similarities, the two fields of study have been different in their focus and trajectory. Of the differences, three are most visible. First, design as research emphasizes the domain in which the design activity will take place, placing a premium on innovativeness. In contrast, researching design emphasizes increased understanding of design methods often independent of the domain. Second, the domains of study for the first subfield have typically been the information and computing technologies as opposed to architecture and engineering for the second. Finally, the closest alliances from the first have been formed with disciplines such as computer science, software engineering and organization science. The latter is more closely allied with cognitive science and professional fields such as architecture and engineering.

The first strand, design as research, emphasized in a research program sponsored by the National Science Foundation (NSF) in the U.S., illustrates the importance of and need for high quality design research. The Science of Design for Software-Intensive System program (NSF 2007) funded research projects to bring together the necessary knowledge and expertise to develop a rigorous science of design for software-intensive systems. The program solicited ideas to broaden the ways in which software design research is conducted, particularly in light of increasing software sophistication, diversity, dependences, and risks. This focus on design as the central theme of this program was intended to raise the level of discourse, generate new interdisciplinary perspectives, and take a more holistic view of the major challenges of building software-intensive systems. The program recognized that significant strides in creative thinking about design have a strong tradition in many scientific, engineering, and artistic disciplines, and sought to import and adapt the best of these ideas while recognizing and addressing the unique nature of software (e.g. its mutability), which differs significantly from other designed artifacts. Funded project goals included the development of new, innovative theories, constructs, models, methods, and/or tools to move software design into the next generation of complex, distributed computing environments.[2]

As the discussion earlier shows, the Sciences of Design have found expression in at least two different communities (without explicitly including others such as product design and engineering design). At the DESRIST conference, similarities and differences across these two streams were explored probably for the first time. We believe that the first Doctoral Consortium at DESRIST, therefore, represents an important marker in the evolution of this emerging field of study.

III. THE FIRST DOCTORAL CONSORTIUM AT DESRIST

It was against the above backdrop of: (a) the desire to define the sciences of design at the intersection of several disciplines; and (b) the continuing struggle to understand how the communities aimed at researching design and design as research may communicate. Thus, the IS discipline saw the formulation of the DESRIST conference. The first two conferences (in 2006 and 2007 respectively)[3] saw significant participation from a number of disciplines, notably computer science, software engineering, and engineering design. These initial conferences drew participation from celebrity designers, funding agencies, and academics who, together, explored ideas underlying design science research. The discussions and presentations in these two events provided the impetus for cross-fertilization of ideas among practitioners and academics across disciplinary boundaries. However, a clear crystallization of ideas did not result, nor was it communicated beyond researchers currently engaged in various forms of design science research. In retrospect, these meetings may be seen as efforts from different disciplinary representatives to assert their jurisdiction over the sciences of design (akin to the arguments from Abbott [1988]).

The core group interested in bringing these interests together persisted. The third DESRIST conference[4] produced a first attempt at coordinating a forum—the Doctoral Consortium—that allowed sharing of experiential knowledge about various flavors of design sciences (from its various adherents and practitioners) to be discussed in a manner that would facilitate its propagation to the next generation of design science researchers. The consortium was supported by the National Science Foundation that recognized the important task of bringing together different disciplines. One way to characterize the consortium is by examining the doctoral students who were attracted and admitted to the consortium. Table 1 summarizes their disciplinary affiliations and geographical locations.

Table 1. Disciplinary and Geographical Breadth

Doctoral Candidate	Disciplinary Affiliation	University and Location
Irene Anggreeni	Industrial Design	U Twente, Netherlands
Pelin Atahan	Management Science	UT-Dallas, Texas, U.S.
Paul Grisham	Software Engineering	UT-Austin, Texas, U.S.
David Gurzick	Information Systems	U Maryland-Baltimore County, Maryland, U.S.
Henrique Houayek	Environmental Design	Clemson U, South Carolina, U.S.
Heekyoung Jung	Informatics	Indiana U, Indiana, U.S.
Lysanne Lessard	Information Studies	U Toronto, Canada
Kafui Monu	Information Systems	U British Columbia, Canada
Brittany Smith	Computer Science	U Illinois-Urbana, Illinois, U.S.
Marlies van Steenbergen	Information Sciences	U Utrecht, Netherlands
Helena Sustar	Human Computer Interaction	City University, London, UK

Table 1 shows that the conference attracted candidates from a wide variety of disciplinary affiliations and universities from a number of geographical locations. The emphasis on computing and information-related disciplines is unmistakable, although the breadth suggests that the consortium also appealed to students from disciplines that often find it difficult to cross boundaries. The students represented a cross-section of universities from the U.S.,

[2] Approximately 50 projects were funded during three years of the Science of Design program at NSF. A listing of funded projects can be found at http://www.research.gov by going to Research Spending and Results, using Advanced Search, and entering 'Science of Design' in the Program.
[3] See http://ncl.cgu.edu/designconference/index.html and http://ncl.cgu.edu/desrist2007/
[4] See http://desrist2008.cis.gsu.edu/

Canada and Europe although representation from universities in Asia and South America was missing. A further analysis was carried out to investigate the research topics and levels of analyses represented (see Table 2).

Table 2. Level of Analysis and Research Topics Presented

Doctoral Candidate	Level of Analysis	Research Topic
Irene Anggreeni	Artifact, Group	Scenario based product design
Pelin Atahan	Individual	Interactive learning of user profiles
Paul Grisham	Artifact, Group	Designing for software maintainability
David Gurzick	Community	Deep design for online communities
Henrique Houayek	Individual, Group	Animated work environments
Heekyoung Jung	Individual	Products with digital interfaces
Lysanne Lessard	Artifact, Organization	Models for service delivery
Kafui Monu	Organization	Agent-based analysis models
Brittany Smith	Individual, Group	Enhancing group creativity
Marlies van Steenbergen	Organization	Enterprise Architecture design
Helena Sustar	Individual	Creativity for senior citizens

The table shows the research emphasis of each student. The column titled "Level of Analysis" indicates the stakeholders who would participate in, be the intended audience for, or be affected by the research efforts undertaken. When the emphasis was squarely on the artifact itself, without an overt reference to the intended audience, the level of analysis is indicated as "artifact" in addition to an inference that points to the intended audience.

The mentors invited to the consortium were seasoned researchers who were known for their contributions to design science research in one or more forms. Table 2 outlines their disciplinary and institutional affiliations.

Table 3. Mentors' Positions on Design Science(s)

Mentor	Self-described Position about Design Science	Institutional, Geographical Affiliation
Carliss Baldwin	Economist with an interest in design	Harvard Business School, Massachusetts, U.S.
Alan Hevner	Computer scientist with an interest in software-intensive systems	U of South Florida, Florida; NSF, U.S. (On Assignment)
Jan Pries-Heje	Information systems expert with an interest in intervention	Roskilde U, Denmark
Brian Smith	Learning sciences expert with an interest in instructional systems	Penn State U, Pennsylvania, U.S.
Veda C. Storey	Modeler with an interest in representing real world concepts	Georgia State U, Georgia, U.S.

The Consortium itself was organized to allow significant time for interactions among students and mentors. Following the practice of allowing students and mentors to work together, the Consortium included the following activities. Each student made a short presentation focused on his or her research topic. This was followed by two breakout sessions. Of these, the first focused on exploring the dissertation topic itself, while the second focused on funding and publication strategies. The day ended with mentors sharing their perspectives on design sciences and providing their insights on the discussions throughout the day.[5]

IV. POSITIONS AND REFLECTIONS FROM MENTORS

The following a priori positions were elaborated by the mentors, and further reflections were added, based on individual insights that emerged from interactions at the consortium. These are reproduced in this section (with edits aimed only at clarification) to ensure that the varied perspectives from the mentors are captured in their own words.

FROM AN ECONOMIST WITH AN INTEREST IN DESIGN (Baldwin)

What brings an economist to study designs? All product and services are the result of some prior effort of design, and thus designs lie at the core of our economic system. Furthermore, innovations, which are the principal source of wealth in modern economies, are precisely changes in designs: "There is at any moment a 'standard' design which

[5] http://www.slideshare.net/SandeepPurao/desrist08-consortium-report

is seen as emerging from the just prior 'standard' design." [Bell and Newell 1971, p. 87]. Thus all studies of innovation are implicitly studies of designs, and design science potentially has a great deal to offer to fields such as economics of innovation, management of technology and new product development.

Because they are a source of wealth, designs are targets of investment in the economic system. In the technical language of finance, they are assets. And because one can always elect not to use a new design (sticking with an older one or simply doing without), new designs are a special type of asset: they are options—"the right but not the obligation" to take a specific action at a later date [Merton 1973; Jarrow 1999].

This is where the established science of economics, specifically finance, intersects with the new design sciences. If new designs are targets of investment—as they are—then those seeking to understand and rationalize investment decisions must seek to understand designs. Understanding designs in turn means understanding their origins (how designs come into existence); their structure (how design decisions depend on one another); and their dynamics (how designs evolve). As it turns out, these three aspects of design behavior are related: origin influences structure, structure affects dynamic potential, and dynamic potential plus investment leads to the creation of new designs.

The first doctoral consortium at DESRIST provided evidence of the great range and variety of inquiries in the nascent science of design. The designs studied by the students included physical objects such as an alarm clock (Jung); an animated work environment (Houayek); software (Atahan and Grisham); services (Lessard); enterprise architecture (van Steenbergen); design support tools (Anggreeni, Monu, Smith, Sustar); and online communities (Gurzick). Their methods were equally diverse, drawn from both engineering and the social sciences. However almost every project involved close analysis of one or a small set of related designs. And most projects had an action component, that is, the researchers were engaged in creating and constructing designs as well as observing them.

The focus on deep understanding of small sets of related designs is appropriate for this young science: there are as yet no generalizations, much less data, to support large-scale empirical analysis.

The emphasis on creation-and-construction as a valid method of investigation is a hallmark of this science and deserves further discussion. Every new design is in effect a hypothesis about a set of causal relationships in the real world: the designer (or design team) predicts, "If I/we set the structure of the artifact in this way, it will function in that way." Clearly, if designs are (implicitly) hypotheses about relationships between structure and function in the real world, then creating a design generates a set of embedded hypotheses and constructing the design (building the artifact) constitutes a test of those hypotheses. Thus designs are by their very nature falsifiable propositions, albeit complicated ones. Hence the creation-and-construction of designs is fully consistent with the scientific method as described by Popper [1989] and others.

This point has lately been made with great force and eloquence by Hevner et al. [2004]. I do not agree that the creation-and-construction of a design should be the sole criterion of a contribution to design science, for such a move would place the new science in a methodological straitjacket. Nevertheless, creation-and-construction needs to be championed as a valid scientific method. This means developing a theory of the method that explains when the method can be applied, what it is good for, what inferences can be drawn from it, and when generalizations are appropriate. It also means we should encourage students (and practitioners) in the design sciences to make explicit the hypotheses embedded in their designs and thoughtfully report the results of their constructive efforts.

Both students and faculty at the consortium had extremely high levels of interest and engagement in the phenomena of designs (in all their guises). However, in the midst of our enthusiasm, a most striking fact was our lack of a common language. We perforce communicated in the languages of our "home" fields: industrial design, computer science, information systems, learning, organizational behavior, and management.

The lack of a common language constitutes a danger to the nascent design sciences. The danger is that our joint efforts will dissolve into incoherence, as exemplified by the myth of the ill-fated Tower of Babel. In the absence of a common language, investigators bring their own descriptions and intuitions to the phenomena. They talk at cross-purposes, apparently waste time, and assemble and report incommensurable results. It is not clear at this stage how the work fits together, and indeed there is a risk that it will not.

However, I believe the design sciences are at the point where it is possible to start building a common language that spans designs of any form, any scale, and any scope—designs of tangible objects, services, experiences, production processes, financial securities, organizations, corporations, markets, and institutions. This was the original vision of Herbert Simon in his path-breaking book, *The Sciences of the Artificial* [1969] but Simon's is not the only perspective that can be brought to bear. I believe that other eminent design theorists in a number of fields, including Christopher Alexander (architecture), Fred Brooks (computer science), David Parnas (computer science), James Thompson (organizations), Nam Suh (mechanical engineering), and John Holland (complexity science) and others share an essentially congruent view of designs and that this view can be the basis of a common language.

The view might be called "an informational theory of design." It holds that designs are essentially instructions for making things (things people use and value enough to make the effort of design). The creation of a design is thus basically the construction of an algorithm; the structure of a design is determined by interdependencies among the elements of the algorithm; and the units of selection/modification are modules (easily separable areas) within this dependency structure.

Kim Clark and I drew on the scholars listed above when we wrote *Design Rules* [Baldwin and Clark 2000], which presents a theory of design evolution based on financial value and incentives. Perhaps because we were outsiders to all design domains, we were more attuned to the commonality of what the authors were saying than the contradictions. Yet if we had not found a core theory of design that worked across domains, we would not have been able to construct a coherent theory of how designs evolve and create value in the economy. Luckily, we found that we could synthesize the views of many different authors without doing great violence to any one. Indeed, in many cases, we found that the views expressed corroborated one another.

I believe that a core theory of design exists and can be synthesized from writings across a number of disparate fields. This, in turn, makes me optimistic about the future of design science. If there is a unified core phenomenon, then there can be a common language. And if a common language exists, there can be an ongoing productive pursuit of scientific knowledge. We can have one science, not many.

But common languages only come about through intense, repeated conversations between individuals with disparate views and open minds. Important conversations took place at DESRIST 2008 and the Doctoral Consortium. They were the beginning of what I hope will be a long and productive series of engagements.

FROM A COMPUTER SCIENTIST WITH AN INTEREST IN SOFTWARE-INTENSIVE SYSTEMS (Hevner)

The development and execution of design science research projects in Information Systems (IS) draw from a long history and tradition of design studies in engineering fields, architecture, the arts, and many other design-oriented communities. As seen in the diversity of the students and the mentors in this doctoral consortium, many different research fields and traditions employ design theories and methods to produce and study useful artifacts in relevant application areas. From my research background in computer science, I have performed design research in the areas of database systems, software engineering, and information systems analysis/design. In order to mentor and guide researchers who are new to design science projects, it is necessary to generalize the best practices of this research paradigm for adaptation to a wide variety of application domains.

The 2004 MIS Quarterly paper with co-authors Sal March, Sudha Ram, and Jinsoo Park [Hevner et al. 2004] sparked considerable interest in design science research as a credible (both rigorous and relevant) form of IS research. Our goal in that paper was to make more visible the role and value of design science research in IS via a concise conceptual model and seven clear guidelines for understanding, executing, and evaluating the research. It is gratifying to note the expansion of design science research methods being taught in IS doctoral seminars at most research universities. Understanding and communicating a well-defined and rigorous design science research process is essential not only to support acceptance among IS professionals but also to establish the credibility of IS design science research among the larger body of design science researchers in the other design-oriented research communities.

In my interactions with the doctoral students in the DESRIST Consortium I found great enthusiasm and interest in the use of design science research methods to solve challenging real-world problems by creating innovative artifacts. A key question was "What makes the design and development of a useful artifact a research project acceptable for publication in top-level research journals? " Our discussions centered on the Three-Cycle View of design science research as found in Figure 2 [Hevner 2007].

Effective design science research must clearly address the inputs and outputs within each of these three cycles. The relevance cycle inputs requirements from the contextual environment into the research and introduces the research artifacts into environmental field testing. The rigor cycle provides grounding theories and methods along with domain experience and expertise from the foundations knowledge base into the research and adds the new knowledge generated by the research to the growing knowledge base. The central design cycle supports the tight loop of research activity that provides the construction and evaluation of design artifacts and processes. The recognition of these three cycles in a research project clearly positions and differentiates design science from other research paradigms.

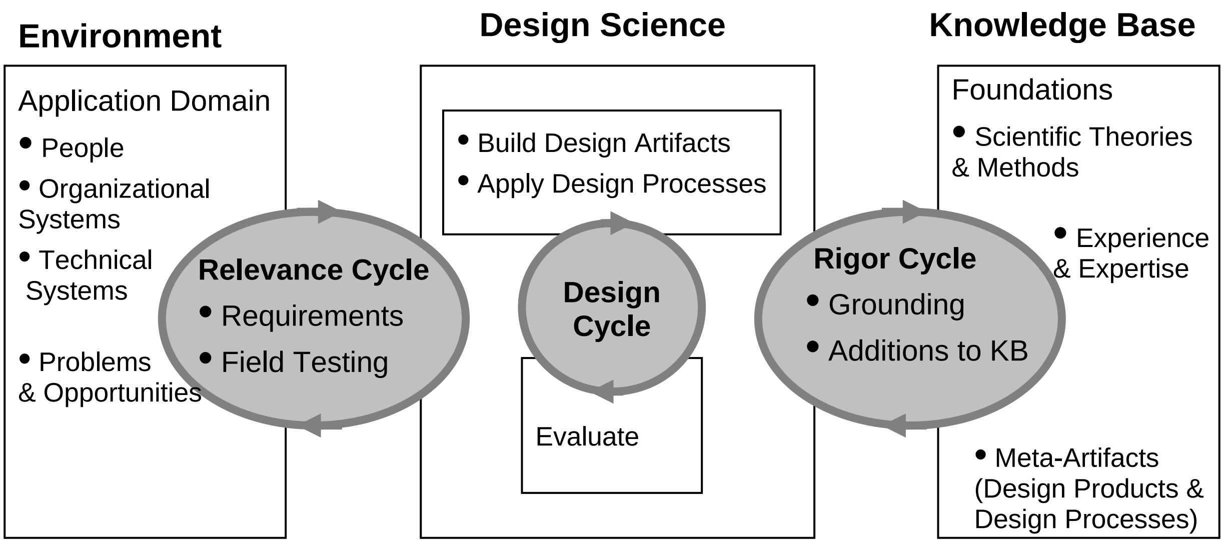

Figure 2. Three Cycles of Design Science Research (Adapted from [Hevner 2007])

The following questions guided the discussions of how each student's research project mapped into the three research cycles:

- What is the Research Question (design requirements)?
- What is the Artifact? How is the artifact represented?
- What Design Processes (search heuristics) will be used to build the artifact?
- How are the Artifact and the Design Processes grounded by the knowledge base?
- What Evaluations are performed during the internal design cycles? What design improvements are identified during each design cycle?
- How is the Artifact introduced into the application environment and how is it Field Tested? What Metrics are used to demonstrate artifact utility and improvement over previous artifacts?
- What new Knowledge is added to the knowledge base and in what form (e.g. peer-reviewed literature, meta-artifacts, new theory, new method)?
- Has the Research Question been satisfactorily addressed?

The students found these questions to form a useful checklist to ensure that their projects address the key aspects of design science research. Our discussion of top-quality publication outlets drew a distinction between journals with technology-focused audiences and management-focused audiences. Good design science research produces results of interest for both audiences. Technology audiences need sufficient detail to enable the described artifact to be constructed (implemented) and used within an appropriate context. It is important for such audiences to understand the processes by which the artifact was constructed and evaluated. This establishes repeatability of the research project and builds the knowledge base for further research extensions by future design-science researchers. On the other hand, management audiences need sufficient detail to determine if organizational resources should be committed to constructing (or purchasing) and using the artifact within their specific organizational context. The rigor of the artifact design process must be complemented by a thorough presentation of the experimental design of the artifact's field test in a realistic organizational environment. The emphasis must be on the importance of the problem and the novelty and utility of the solution approach realized in the artifact.

FROM AN INFORMATION SYSTEMS EXPERT WITH AN INTEREST IN INTERVENTION (Pries-Heje)

One view of research is that it is about achieving a better understanding of phenomena. Natural science seeks to understand natural phenomena while behavioral science tries to understand the phenomena revolving around human behavior. Another view of research is that it is about finding better ways to achieve given ends and guidance about how to act in the world. Design science research incorporates knowledge about phenomena from both natural and behavioral sciences to develop means and prescriptions as an approach to achieve human goals.

To me, the special thing about design science research is that your knowledge and understanding of a problem domain and its solution are achieved through the building and application of a designed artifact; you build to learn from it. This is characteristic of any kind of design of course. So what makes the building or construction research is a key question. One answer is that when researchers design something it must be design research. Another answer is that if one uses good research methods to design and evaluate, then it becomes design research. And a third answer is that you have to relate to what others have done within the design domain you are working in; and the relation should be both that you make clear what others have done before, and that you clarify what is new in your design. Of these three answers, I prefer a combination of two and three; whether design research is carried out by a researcher I do not consider important.

Another important thing is that in design research you have an artifact as outcome. Not many scientific disciplines have this distinguishing feature. In that sense information systems as a research area is like shipbuilding. Ships can be studied scientifically. You can develop theories about ships; speed, stability, durability, maintainability, and so on. But most research is done through building and applying.

Design science research can be considered a meta-method focused at developing understandings and principles. However, design science research is in itself an innovation. First because design science research more than just replicates the industrial engineering method. It unites principles from this more deductive logic with principles from inductive sociological and anthropological observation. In this respect, design science research differentiates itself from, for example, cybernetics. Second, design science research can be considered a general social technology (different from the chemical and physical industrial technologies) that must be seen as an integrated part of social systems. Finally, because design science research is at a clear meta-level it will reflect critically upon the methods used in innovation, production and delivery of experiences and services. These reflections will, for example, include questions such as how artistic creativity can beneficially be combined with systematic IT-methods.

When you build to learn you often realize that the first artifact does not solve the problem at hand in a satisfactory way. Therefore the design process becomes iterative. Fred Brooks in his book *The Mythical Man-Month* talked about planning to throw one away, but my experience is that two iterations would not be enough. When I have been carrying out design research, three to four iterations have been necessary before the artifact was a satisfactory solution in the problem domain. Many people confuse action research with design research. To me design research can be carried out in an action research way. The iterative cycle is a core part of action research and as said above many design efforts will need several iterations to become good enough. However, design research can be carried out in artificial settings not involving any intervention in a natural setting or cooperation with people from the problem domain. Thus design research can be action research but does not have to be.

The relation between innovation and design research is quite obvious. The most common definition of innovation is that the user shall experience it as something new. In most cases when you develop information systems the result is experienced as new by the users. Then, if the artifact being constructed in a design research effort is a new system, it will often be seen as an innovation.

The most interesting thing to me at the Doctoral Consortium was that it brought together people with very diverse topics from within and outside the IS discipline. From designing personalized Web-pages or online communities, over using creativity tools and model actors, to looking at organizational IT through the glasses of enterprise architecture. It became clear that a design science approach is useful, not only across the board of within the IS discipline, but also beyond.

Many of the discussions I had in my group of Ph.D.-students concerned the research approach when performing design research. The discussion above on action research and how it is related to design research also emerged in the group. Further, a couple of students were using grounded theory techniques to ensure enough rigor in the analysis, and our discussion in the group concluded that this probably was a good idea.

FROM A LEARNING SCIENCES EXPERT WITH AN INTEREST IN INSTRUCTION (Smith)

When I first began my faculty position at Penn State, I was often asked if I was a qualitative or quantitative researcher. I was fascinated by the question for several reasons. First, it had never occurred to me to describe myself in terms of a particular research methodology. Instead, I define myself in terms of the questions I seek to answer, the problems I try to solve. Most of these relate to educational issues, how to help people learn in new ways.

Second, I was surprised that there were only two choices, qualitative and quantitative. If anything, I consider myself a design researcher since I create interventions, deploy them into the world, and try to understand their successes and failures. Education research is tightly connected with interventions, since much of what occurs in learning environments such as schools, museums, and corporate training are designed to help individuals and group acquire knowledge and skills. My field, the learning sciences, has long embraced design methods in efforts to create interventions that facilitate learning while simultaneously studying their effects and using these studies to advance knowledge about how people learn in different settings.

My research is typically classified under the terms design experiment [Brown 1992; Collins 1992] and/or design-based research [Design Based Research Collective 2003]. Design researchers begin with initial hypotheses and principles that guide their design and go through an iterative process of implementation, collecting evidence, and using this evidence to redesign their artifacts. Each cycle gradually elaborates hypotheses into coherent theories about the nature of learning and instruction and the design process itself. As opposed to idealized, linear models and frameworks, design research acknowledges the complexity of real learning contexts and relies on numerous iterations to move toward theoretical generalizations.

The initial stages of design studies are often exploratory, seeking to understand the possibilities that emerge as a result of people interacting with designed artifacts. This differs from more traditional education research where well-defined hypotheses are articulated and interventions serve the purpose of providing concrete products that can be tested to confirm and/or refute initial hypotheses [Cobb 2000]. As a result, many education studies do not include rich descriptions of designed interventions as they only provide the means to a larger goal of testing existing hypotheses.

In contrast, design researchers believe that that design plays a role in evaluating and generating hypotheses [Edelson 2002]. In fact, all designed artifacts are created with some set of assumptions, principles, and/or theories in mind. Design research methodologies stress the need for making these assumptions and rationales explicit and collecting evidence to support and/or refute them. Thus, we can talk about theories of learning, but we can also create interventions that embody these theories and help us elaborate the extent to which they apply to particular contexts and situations.

As an example, Brian Reiser and I conducted early design experiments around a video annotation system in biology classrooms. Science education research gave us initial insights into the ways that students explained biological phenomena, and we used these findings to design our interventions. Over five iterations in classrooms, we gradually learned new things about the ways that students observed and interpreted animal behavior. These iterative findings eventually resulted in a general framework for facilitating constructive observation and inquiry in science classrooms [Smith and Reiser 2005]. We could have simply presented our final theoretical perspective, but it was equally important to articulate our rationale for modifying our designed interventions over multiple deployments [Smith and Reiser 1998]. Each of the iterations led to improvements in our software, but more importantly, each deployment session gave us new insights into student learning that were applied to new designs and evaluated in classrooms.

None of the DESRIST doctoral consortium students were studying educational technologies, but they were concerned with the use of design to generate new knowledge as well as practical applications. After 11 research presentations from a number of disciplines, it was interesting to talk with teams of students about the similarities and differences in their design approaches. Much as quantitative and qualitative researchers can discuss methodological issues independent of the phenomena they're studying, we were able to hold domain-general discussions about the artifact and theory building that is part of design research efforts. This generalization of methods is important for the future of design science research.

One challenge that I talked about with students is determining when to stop iterating and commence summative evaluations of an intervention. Unfortunately, I am not aware of a strong formula or method that can be used to decide when to shift from iteration to evaluation. The types of questions being investigated, the nature of the intervention, and the contexts being studied are just some of the factors that will influence the number of iterations needed to move from strictly "making things" to developing theories about how and why the "things" work.

One oft-cited paper on design-based research in the learning sciences was written by the Design-Based Research Collective [2003], a group of young scholars that had received their doctoral degrees and were just beginning their professional careers. Those researchers were willing to risk the uncertain timelines for conducting studies and finishing dissertations in order to embrace and advance design studies in our field. I was pleased to see the DESRIST doctoral consortium students equally willing to jump into design studies that will, no doubt, advance theoretical perspectives in their domains. Since this is still an emerging field, I suspect that the next advances in design science will come from young researchers like the DESRIST panelists. In fact, they, like the Design-Based Research Collective, may come together to generalize their methods and write the next article for this journal on design science across multiple domains. Having seen their individual research efforts thus far, I am confident that their collective efforts would produce new perspectives on design that would lead people to ask, "Are you a qualitative, quantitative, or design researcher?"

FROM A MODELLER WITH AN INTEREST IN REPRESENTING REAL WORLD CONCEPTS (Storey)

There are a number of similar challenges between design science research and conceptual modeling that deal with our endeavors to capture something in the real world, represent it, and perform analysis based upon that representation. These challenges are driven by the artifact itself, its development, and evaluation. Conceptual modeling deals with representing a part of the real world in such a way that it can be understood and analyzed. Similarly, the artifacts developed by researchers in design science must be represented so that they can be understood, applied, and evaluated by others. An artifact has the best chance of being accepted as a valuable contribution if it is new, novel, and addresses a problem previously not solved or not solved in an efficient or practical way.

A theory base that can drive the need for an artifact is most useful in guiding the design of the actual artifact. There are many theories from which to draw, spanning a variety of disciplines. Evaluation of an artifact poses a major challenge. One of the most effective approaches is to develop a prototype and conduct a thorough empirical analysis. This may not be feasible for certain types of artifacts, such as frameworks. Expert feedback, case analysis, and other forms of proof of concept are often used.

The DESRIST doctoral consortium was significant in that it provided an opportunity to interact with emerging researchers in a variety of academic areas. The topics and approaches to addressing the research questions were diverse and interesting. Some of the topics were very application driven; others focused on developing a theory base. Contemporary topics were emerging based upon the latest web 2.0 developments and advances. Some of the students were very ambitious and illustrated the scoping problems that can occur. When driven by real-world applications, challenges can arise in positioning the work. Finally, design science research is proving to be a great outlet for creative work.

V. OPPORTUNITIES AND CHALLENGES

The positions and reflections in the previous section underline several recurring themes as well as new perspectives related to the sciences of design. In particular, some of the reflections from mentors capture their personal journey toward design sciences as well as how the journey has come to shape their own orientations toward this mode of research. A complete synthesis of these positions and world-views would require much more than a short paper. Nonetheless, a synthesis is warranted because it can identify potential avenues of future work. In developing the observations outlined following, we have drawn on the following sources: (a) a potential theoretical perspective of a system of professions [Abbott 1988] outlined earlier; (b) position statements and reflections from mentors in the previous section, and (c) extensive notes taken at the consortium detailing student presentations and discussions. Each observation is interpreted as both, an “opportunity” and a “challenge,” the former suggesting possibilities for advancement and the latter pointing to obstacles that must be overcome as this emerging field of study advances.

Observation 1: The Plurality of the Sciences of Design

Our first observation concerns the fundamental question that continues to be discussed within this nascent community: what constitutes design science research? Even as the mentors argued for the legitimacy of design sciences (in the words of one mentor: “I was often asked if I was a qualitative or quantitative researcher”) they continued to look for clear definitions that would be widely applicable.

We posit this definitional flux is a likely consequence of the plurality of research orientations seeking home under the banner of design sciences. The first claimants to the design sciences (design science or design research) terminology include the group of researchers that have been self-organized under the nomenclature of design research community and established over the last few decades. The primary focus of these researchers is the study of design, designing, design processes and design behaviors at a number of levels of analyses. The group has established credibility and demonstrates signs of disciplinary reward structures including professional journals and fellowships from the design research society. The second claimant to the design research terminology is the group of researchers that views design *as* research. This group of researchers focuses on the act of design, primarily (but not exclusively) in the domain of information technology, as the mode of knowledge creation. The artifacts they create and the methodologies they devise represent the research outcomes that this group of researchers values. The gap was noted by another mentor who noted that it is necessary “to communicate across the perceived chasm between the terminology used by the design research society and the DESRIST community.”

The new participant in this discussion, the design science research community within the IS discipline, has now begun to establish credentials with publications in major journals [Hevner et al 2004], initiating conferences such as

DESRIST and the doctoral consortium that this paper reports on. Following this redefinition of the debate to include design *as* research as a candidate within the definition of design sciences, the group of researchers within the IS discipline should continue to build bridges with the rich tradition in allied fields such as the design research society. Following Abbott's [1988] arguments, one may predict that this plurality under the banner of design sciences is likely to become significant as these two communities attempt to negotiate claims of jurisdiction. One of the mentors, for instance, recognized this problem by noting the following: "I do not agree that the creation-and-construction of a design should be the sole criterion of a contribution to design science, for such a move would place the new science in a methodological straitjacket. Nevertheless, creation-and-construction needs to be championed as a valid scientific method."

A potential approach to the negotiation between the two claimants to design research terminology that surfaced during the DESRIST doctoral consortium was the possibility that each community may view the other as addressing a subset of concerns. For example, from the perspective of the IS discipline, the study of design behaviors may be viewed as an important component of design science research. One of the mentors, for example, described design *as* research in the following words: "design researchers begin with initial hypotheses and principles that guide their design and go through an iterative process of implementation, collecting evidence, and using this evidence to redesign their artifacts. Each cycle gradually elaborates hypotheses into coherent theories about the nature of learning and instruction and the design process itself." The description points to the possibility that the two research activities (a) the iterative design of an artifact and (b) understanding the design process itself may be viewed as complementary activities. Another mentor noted that "design science research can be considered a meta-method focused at developing understandings and principles" further echoing this possibility. Precursors to such overtures exist within IS in the form of Lee's efforts to compare the discipline with Architecture [Lee 1991].

Several other reasons may be cited for such inclusion. First, overcoming cognitive roadblocks in design is an important sub-stream in design science research (see, e.g. [Batra and Davis 1992; Purao et al. 2003]). Understanding design behaviors may, therefore, be seen as an important pre-requisite for improving the design processes or providing scaffolding for them (a concern that design science researchers are likely to focus on). Second, research outcomes that focus on understanding design behaviors may provide better clues for focusing research efforts aimed at devising prescriptive methodologies and constructing artifacts. Third, constraints uncovered in design behavior studies may provide effective parameters around which design science efforts may be organized. We surmise that similar arguments may be put forward positioning design *as* research as a subset of concerns valued by the design research society, perhaps following arguments related to designerly ways of knowing [Cross 2007].

Opportunity

The opportunities following this observation clearly lie in the learning across disciplines that is likely to result from such dialog. The potential cross-fertilization of ideas and research efforts that such dialog may bring about will not only enrich the terminology but will deepen the understanding of the different flavors of design sciences in each discipline. In addition to a deeper understanding of the field of study itself, it is possible that the dialog will preempt any possible concerns related to jurisdiction that may arise as the fields progress.

Challenge

While the opportunities that follow this observation are obvious, the challenges require some reflection. Two specific challenges, related to differences between these two strands of design science, may make the cross-fertilization of ideas difficult. The first concerns the role of domain expertise, which is a prerequisite for design *as* research. On the other hand, it is possible to argue for domain-independent outcomes when the focus is on researching design. The second concerns methodological challenges. While design *as* research subscribes to learning via building, conventional approaches to understanding design consider design and designing as phenomena like any other that should be studied. Balancing the two strands may, therefore, be a challenging proposition, albeit with a significant payoff.

Observation 2: Bridging the Inherent Multi-Disciplinarity with a Common Language

Building on the discussion earlier, the consortium clearly demonstrated the need for a common language. A potential contributor to the diversity of perspectives was the different disciplinary backgrounds that students were drawn from (Table 1). As one of the mentors noted, "The first Doctoral Consortium at DESRIST provided evidence of the great range and variety of inquiries in the nascent science of design … almost every project involved close analysis of one or a small set of related designs. Most projects had an action component, that is, the researchers were engaged in creating and constructing designs as well as observing them." The problems were evident, at least in part, in the presentations from the doctoral candidates. Each had to work hard to clearly describe and present to the mentors what they were doing and how. One of the mentors recalled the experience as: "in the midst of our enthusiasm, a most striking fact was our lack of a common language. We perforce communicated in the languages of our home'' fields: industrial design, computer science, information systems, learning, organizational behavior, and management." The presentations and the discussions also pointed to a potential problem that a mentor noted in retrospect: "The lack of a common language constitutes a danger to the nascent design sciences. The danger is that our joint efforts will dissolve into incoherence, as exemplified by the myth of the ill-fated Tower of Babel." Another mentor held out the hope that the students who attended this inaugural doctoral consortium actually represented a group similar to the "Design Based Research Collective" within the learning science disciplines who risked uncertain timelines in order to embrace and advance design studies in that field. He offered the possibility that "the DESRIST doctoral consortium students … will advance theoretical perspectives … [and] … that the next advances in design science will come from young researchers like the DESRIST panelists." Another noted that it was possible to "share an essentially congruent view of designs and that this view can be the basis of a common language."

We are optimistic about this possibility. Among the many writings about design, some have focused on simplicity and aesthetics [Maeda 2006], others on performance [Dasgupta 1996] and yet others on the interactions among artifacts and the environment [Simon 1996]. The terminology that these perspectives use is often at odds with one another. Similarly, the different flavors of design sciences discussed above present different orientations. The disciplinary perspectives on design science add a further level of complexity [Suh 1990; Suh 2001; Cross 2007; Vaishnavi and Kuechler 2008]. One possibility that stands out as a significant contributor to a common language is work by Alexander et al. [1977], who pointed to and exemplified the notion of patterns as a key building block for designs as well as design behaviors. In his view, patterns provide a meta-language that has been shown to span disciplines. A second possibility is the taxonomy developed by Lidwell et al [2003]. Their efforts provide a lexicon of design drawing on a wide variety of sources. Consider, for example, a very small subset of terms included in their compilation: affordances, expectation effect, hierarchy, and satisficing. Meta-languages such as that by Alexander *et al*. [1977] and lexicons like the one by Lidwell et al [2003] can provide an excellent starting point for building a common language that can bridge the inherent multi-disciplinarity of the design sciences.

Another idea that surfaced during the doctoral consortium dealt with the value-orientations of the different students and mentors. One aspect of academe where these possible conflicts can surface is the use of and adherence to different methodologies. As one mentor noted, "creation-and-construction of a design [as] the criterion of a contribution to design science … would place the new science in a methodological straitjacket." On the other hand, another mentor emphasized a view of design science research that "centered on the three-cycle view" consisting of a relevance cycle, a rigor cycle and a design cycle. A third noted that "design science research is in itself an innovation … because design science research more than just replicates the industrial engineering method. It unites principles from this more deductive logic with principles from inductive sociological and anthropological observation." Taken together, these comments indicate the need for a broader perspective on a common language and capturing the multiple value-orientations of the design sciences. Such a language may address not only characteristics of the designers and design processes but also the designed artifacts and the environments in which the artifacts are intended to operate.

Opportunity

Developing a common language that bridges the multiple disciplines that are part of the design sciences may be an opportunity that is appropriate for researchers in the IS discipline with its varied strands. Following Lyytinen and King's characterization of the IS discipline as one that encourages boundary-spanning [King and Lyytinen 2004; Lyytinen and King 2004], such an agenda may provide a fruitful research direction for the IS researchers.

Challenge

Two challenges must be overcome if the opportunity is to be realized. First, although it might be tempting and, perhaps more feasible, to develop a taxonomy that is focused on a specific discipline, such efforts may prevent recognition of the multi-disciplinary nature of design sciences. Second, perhaps more difficult challenge deals with the possibly conflicting value-orientations among the researchers engaged in various forms of design sciences. A common language without common value-orientations may be difficult to achieve.

Observation 3: The Role of Substantive Knowledge and Ways of Doing

The third observation comes from the implicit struggle between the role of substantive knowledge and ways of doing that was witnessed at the doctoral consortium. Substantive knowledge is also described as deep domain knowledge. The source of domain knowledge may be theory or theories about the phenomenon being investigated. For example, one of the students at the doctoral consortium described a way to design aids to foster creativity in senior citizens that combined theoretical perspectives from cognitive science and product design. It was clear that the deep substantive knowledge these perspectives provided were a significant source of inspiration for the research outcomes. Another student described the development of an approach to learning of user profiles that drew upon and sometimes, extended existing techniques for manipulation and interpretation of data streams. In this instance, the emphasis was largely on use and extension of techniques, aka, ways of doing. The two clearly represented different modes of emphasis.

Stressing the importance of the first, one of the mentors noted that "a theory base that can drive the need for an artifact is most useful in guiding the design of the actual artifact." Similar arguments have been made about the need for deep versus shallow knowledge within the information systems development research community [Vitalari and Dickson 1983]. The use of domain-specific theories to illuminate the phenomena of interest was also underscored by another mentor, who pointed out that the "relevance cycle inputs requirements from the contextual environment into the research and introduces the research artifacts into environmental field testing." Another mentor described this importance by pointing to difficulties associated with design sciences: "when driven by real-world applications, challenges can arise in positioning the work."

The importance of the second mode of emphasis, ways of doing, was clear in a point made by one of the mentors: "the rigor cycle provides … methods … from the foundations knowledge base into the research." Another mentor described this in the following manner: "Much as quantitative and qualitative researchers can discuss methodological issues independent of the phenomena they're studying, we were able to hold domain-general discussions about the artifact and theory building that is part of design research efforts. This generalization of methods is important for the future of design science research."

We believe that this balancing between the two demands: the role of substantive knowledge (via theory or theories) and the ways of doing things (via methods or accepted analytical techniques), is particularly important for design sciences although we agree that some balancing between the two is needed for all modes of research. What distinguishes at least one form of design sciences from other modes of research is the importance of innovative outcomes, making deep domain knowledge a key pre-requisite. As one of the mentors noted: "the relation between innovation and design research is quite obvious … if … the artifact being constructed in a design research effort is a new system it will often be seen as an innovation." Establishing such newness of the artifact requires that the design researcher possess a deep knowledge of the phenomenon aided by one or more theories that draw on one or more disciplines.

The balancing between deep substantive knowledge and ways of doing was also manifested in another manner in the comments from mentors. Several of them indicated the need for iteration. One stated: "When you build to learn, you often realize that the first artifact does not solve the problem at hand in a satisfactory way. Therefore the design process becomes iterative." A second mentor indicated: "The types of questions being investigated, the nature of the intervention, and the contexts being studied are just some of the factors that will influence the number of iterations needed to move from strictly 'making things' to developing theories about how and why the 'things' work." A third noted: "Effective design science research must clearly address the inputs and outputs within each of these three [Relevance, Design and Rigor] cycles … The recognition of these three cycles in a research project clearly positions and differentiates design science from other research paradigms."

Opportunity

A significant opportunity that follows this observation is the possibility of delineating different ways of defining and conducting research projects that fall under the umbrella of design sciences. A potential start towards this outcome was the idea of an anatomy of design theory that was proposed by Gregor and Jones [2007]. Another example is the investigation of multiple epistemologies for design sciences [Niehaves 2007]. Such descriptions provide useful platforms for investigations into multiple flavors that the design sciences can support.

Challenge

Like the other observations, the challenge that is underscored by this observation is again, one of balancing. The two demands of deep substantive knowledge and knowledge about ways of doing may require that effective design science outcomes are necessarily a team endeavor. Carving out effective design science outcomes that respect these demands may require explicit recognition of different flavors of design sciences.

Observation 4: The Recognition of Different Domains and Levels of Analyses

The positions from the mentors as well as those presented by students admitted to the consortium presented a wide array of examples of design science research. The outcomes were not only representative of work in varied disciplines, but also demonstrated different domains in which the researchers intervened (Table 1) and different levels of analyses (Table 2). Although this was evident in the presentations from students, we note that such explicit recognition is not part of our understanding of design sciences yet. Expanding the concern related to a common language outlined earlier, one of the mentors noted the need for "language that spans designs of any form, any scale, and any scope." Our own identification of the levels of analyses for each research effort presented at the consortium (Table 2 earlier) emphasized this variety and pointed to the need for a concerted effort to explicitly recognize such levels. Not only would this allow the identification of appropriate theory sources and techniques (see Observation 3) but would also point to a potential decomposition of concerns at different levels and a multi-level taxonomy (see Observation 2).

A related concern that was identified by several mentors was the overlap between design and action, with multiple interpretations of the word “action.” For example, one of the mentors noted: “Design research can be carried out in an action research way. The iterative cycle is a core part of action research and … many design efforts will need several iterations to become good enough. However, design research can be carried out in artificial settings … Thus design research can be action research but does not have to be.” Another described projects discussed at the consortium as: “Most projects had an action component, that is, the researchers were engaged in creating and constructing designs as well as observing them.” The idea of action was also interpreted by one mentor in terms of a future potential, for example, as: “New designs are a special type of asset: they are options—‘the right but not the obligation’ to take a specific action at a later date.” Yet another mentor described action in terms of an evaluation effort: “Management audiences need sufficient detail to determine if organizational resources should be committed to constructing (or purchasing) and using the artifact within their specific organizational context.” Yet another mentor described the student presentations thus: “They were concerned with the use of design to generate new knowledge as well as practical applications” recognizing the action component as a pragmatic element.

Together, these pointers suggested the importance of the environment as one that is likely to undergo contemporaneous changes when an information technology artifact is design and deployed. The recognition of multiple domains and levels of analyses, together, presented the possibility of non-linear research approaches where the outcomes may include not only contributions to building and testing theories but also resulting changes to the domain under investigation.

Opportunity

A significant opportunity that follows from this observation is the potential that it presents to several disciplines to reclaim the ground they may have lost in terms of contributions to society (for example, as evidenced in the IS discipline by ongoing debates related to relevance versus rigor). Not only is “action” a significant component of the design sciences, it can be driven from several theoretical perspectives (at different levels of analyses) to address concerns that may be valued by different communities. A second significant opportunity is the possibility that multiple flavors of design sciences would be identified at different levels of analyses and at the intersections of technological, human, organizational and societal domains.

Challenge

One key challenge from this observation may be traced to the difficulty of meaningful interventions and design efforts at large scales. This challenge would be particularly important for the design *as* research view of design sciences. With greater levels of analyses, the number of stakeholders and the problem complexity can quickly escalate, making design a difficult endeavor. Not only will such efforts need skills from large and heterogeneous teams of researchers but will also require larger outlays of effort and investment and long timelines. Innovative strategies such as study of path creation efforts [Boland et al. 2003] may prove useful in such cases.

Observation 5: A Focus on Multiple Methodologies for Conducting Design Science

Extending the discussion about the distinction as well as potential overlap between substantive knowledge and ways of doing (see Observation 3), this observation (a) recognizes the need for multiple methodologies for conducting design sciences; and (b) notes the need for developing domain-independent prescriptions of such methodologies. At the consortium, some discussions between the students and mentors did progress toward this ideal. One mentor specifically noted this by comparing the design sciences to the more established modes of research: “Much as quantitative and qualitative researchers can discuss methodological issues independent of the phenomena they’re studying, we were able to hold domain-general discussions about the artifact and theory building that is part of design research efforts. This generalization of methods is important for the future of design science research.” This domain-independence in research methods is desirable because it allows communication across disciplines as well as training the next generation of design scientists.

Another mentor found overlaps between potential methods for design sciences and those outlined in other research modes: “The discussion above on action research and how it is related to design research was also brought up in the group … a couple of students were using grounded theory techniques to ensure enough rigor in the analysis, and our discussion in the group concluded that this probably was a good idea.” Yet another mentor found “evidence of the great range and variety of inquiries in the nascent science of design … Their methods were equally diverse, drawn from both engineering and the social sciences.” Together, these comments suggested that potential research methods for the design sciences did not represent a set that was completely new. Although it was acknowledged that some new research methods would be needed, the potential to borrow, extend and refine methodological guidance from more conventional modes of research was recognized. Whether the choices made by the students in describing their research methods were dictated by the desire for legitimacy or the realities of methodological choices is difficult to discern. However, the choices they made offered a glimpse of the potential reuse and sometimes, re-branding of conventional research approaches for the design sciences along with the need for clearly specifying unique research methods appropriate for design sciences. Part of the effort should also include, as one mentor noted: “Developing a theory of the method that explains when the method can be applied, what it is good for, what inferences can be drawn from it, and when generalizations are appropriate.”

Many of the concerns outlined in this observation can be viewed as the natural consequence of the other observations. For example, observations 2 and 4 point out the need for a common language and yet, emphasize the different domains and levels of analyses, respectively. Observation 3 points to specifically recognizing ‘ways of doing’ as a significant contributor to the design sciences. Together, these can be interpreted as the need for articulation of domain-independent research methods appropriate for different flavors of design sciences.

Opportunity

The opportunity that this observation points to is straightforward. There is a dearth of statements that clearly articulate variations of research methodologies for design sciences. The oft-cited paper by Hevner et al [2004] has set in motion a view of design *as* research. How this can be translated, extended and refined into actionable statements that guide research efforts in several domains and at different levels of analyses remains an open concern.

Challenge

A corresponding challenge is one that requires understanding how the problems of design can be different in different domains and at different levels of analyses. Here, the complementary nature of “design *as* research” and “researching design” (see Observation 1) can contribute significantly. With greater understanding of problems related to design and design processes at different levels, it will become easier to outline methodological statements.

Observation 6: Disseminating Results to Multiple Audiences

The mentors noted and the students demonstrated realization that design science researchers must take care to disseminate their results in different ways to reach the right audiences. One mentor, for example, argued: “Good design science research produces results of interest for both audiences. Technology audiences need sufficient detail to enable the described artifact to be constructed (implemented) and used within an appropriate context. On the other hand, management audiences need sufficient detail to assess whether organizational resources should be committed to constructing (or purchasing) and using the artifact within their specific organizational context.” Similar ideas were expressed by another mentor who pointed out: “The DESRIST doctoral consortium students … were concerned with the use of design to generate new knowledge as well as practical applications.” A third described the nature of the artifact as: “An artifact has the best chance of being accepted as a valuable contribution if it is new, novel, and addresses a problem previously not solved or not solved in an efficient or practical way.” Another comment from a mentor interpreted this concern as one of relevance: “The rigor of the artifact design process must be complemented by … the artifact’s field test in a realistic organizational environment. The emphasis must be on the importance of the problem and the novelty and utility of the solution approach realized in the artifact.” Yet another, however, noted: “When driven by real-world applications, challenges can arise in positioning the work.”

Together, these comments point to the need to ensure that the research outcomes from design sciences be communicated not only to the users and in environments they are expected to contribute but also in appropriate research outlets such as conferences and journals to build a cumulative body of knowledge. A further source of complexity is the potential contribution from multiple theoretical perspectives and disciplines to the design science effort. Returning to multiple home disciplines and communicating the research outcomes to these audiences can be a significant challenge. A potential pitfall in achieving this goal was recognized by another mentor: “The focus on deep understanding of small sets of related designs is appropriate for this young science: there are as yet no generalizations, much less data, to support large-scale empirical analysis.” In the absence of such generalizations, it is difficult to outline accepted ways of disseminating results to different audiences. The researchers in the design sciences, therefore, tend to either fall back on traditional reporting modes or invent entirely new genres of reporting the research results. With both, the acceptance hurdles they face for academic outlets can be non-trivial. For following the traditional mode, one of the mentors had the following suggestion: “we should encourage students (and practitioners) in the design sciences to make explicit the hypotheses embedded in their designs and thoughtfully report the results of their constructive efforts." The second mode, inventing new genres of reporting research outcomes may be taken up as a challenge by more seasoned researchers.

Opportunity

The observation is primarily positioned as a challenge of ensuring that the outcomes of design sciences are positioned appropriately for consumption by academic audiences. However, within this challenge resides the opportunity of making a contribution to improving the world. Regardless of the domain and level of analysis chosen, every design science project holds within it the potential to contribute to a set of goals and values held dear by some stakeholder(s). Outcomes of value, therefore, include not only research outcomes but also the artifacts themselves such as physical things as well as technology artifacts [CRA 1999].

Challenge

The challenge, clearly, is one of positioning the outcomes in a manner that would be acceptable in the highest caliber research outlets including archival journals as well as conferences aimed at fast-paced research outcomes. Design science researchers should, therefore, aim to find credibility by appealing to appropriate theoretical bases as well as methodological regimes until more detailed research methods within the design sciences paradigm emerge.

Observation 7: Preparing the Next Generation of Researchers in the Design Sciences

One of the students at the doctoral consortium presented a research project that had distinct inputs and influences from several advisors who had disciplinary backgrounds that varied from engineering and anthropology among others. This student ended the presentation with the following set of questions: How does one prepare oneself to do design science research, and what courses should one take in preparation to be a design science researcher? These questions and several others, inferred from the presentations and discussion, were a key outcome from the consortium. The mentors as well as students realized that the doctoral consortium generated several questions. Unlike consortia in more established fields, where the emphasis is on inculcating a set of values, approaches and methods; the doctoral consortium at DESRIST could be characterized as a mutual sharing and reinforcement of a world-view that was largely shared among the participants.

Nevertheless, important concerns did surface, aimed at questions such as the following: (a) What are the core elements of a body of knowledge that must be available to the next generation of design science researchers? (b) What is the appropriate toolkit, including theories, ways of doing and methodological prescriptions, for the next generation of design science researchers? As well as a key question that still remains unanswered: what are the fundamental concepts researchers need to know in order to effectively contribute to the sciences of design?

In retrospect, the reflections from mentors may be seen as different reactions to these observations. For example, one mentor observed: "Some of the students were very ambitious and illustrated the scoping problems that can occur." Although scoping problems can be common for novice researchers, the nature of design (as wicked problems [Rittell and Weber 1973] and the complexity inherent in design *as* research is likely to further exacerbate the problem. Without useful prescriptions, precursors and exemplars, design science researchers can find it difficult to define the scope of their efforts. Another mentor apparently recognized the problem but elected to see a silver lining: "I suspect that the next advances in design science will come from young researchers like the [students at the consortium] … they … may come together to generalize their methods and write the next article … on design science across multiple domains." This mentor also noted: "Their collective efforts would produce new perspectives on design that would lead people to ask, 'Are you a qualitative, quantitative, or design researcher?'"

Another approach to understanding the problem is the disciplinary lineage and adherences displayed by the mentors and the students alike. With one possible exception, the students owed their disciplinary allegiance to traditional disciplines. The mentors as well were housed in mostly traditional disciplinary units, and as their self-described positions indicated, they viewed themselves as bringing a set of tools from their home disciplines to the new sciences of design because of their interests. As one mentor reflected: "In the absence of a common language, investigators bring their own descriptions and intuitions to the phenomena. They talk at cross-purposes, apparently waste time, and assemble and report incommensurable results. It is not clear at this stage how the work fits together, and indeed there is a risk that it will not."

This comment, more than any other, pointed out that in spite of the enthusiasm displayed by the students and noted by the mentors, real problems remain in articulating values, prescriptive statements, and methodologies for (sensitizing the current set of reviewers and editors, and) preparing the next generation researchers in the sciences of design.

Opportunity

The doctoral consortium provided a significant opportunity to surface the concerns we have outlined above, helped coalesce thoughts and pointed to potential avenues to building a body of knowledge. The conversations at the consortium and those following, which are reflected in this paper, are not solutions but rather, opportunities to continue the debate and discussion.

Challenge

Although domain-independent patterns are beginning to appear for design *as* research (e.g. [Vaishnavi and Kuechler 2008]), it still remains easier to get drawn into deep domain knowledge and end up paying less attention to the techniques and methods of the design sciences. The problems may be traced, at least in part, to the biases that are likely to continue with our own disciplinary allegiance. Overcoming these is an important challenge in preparing the next generation of design scientists.

VI. CONCLUDING REMARKS

This article examined the Sciences of Design as an emerging field of study that cuts across disciplinary boundaries drawing on the reflections of mentors and experiences at the Doctoral Consortium held at the DESRIST 2008 conference. As the first such Doctoral Consortium, we hope that this consortium will, in time, be seen as a significant marker in the evolution of this field of study. This paper has captured reflections from individual mentors, and developed a synthesis of positions that can provide a useful agenda for clarifying and articulating important strands of the emerging Sciences of Design. The observations we have outlined in the penultimate section represent this synthesis. We acknowledge that the observations may be seen as overlapping. We prefer to characterize them as inter-related and complementary, where each emphasizes an important aspect of the emergence of design sciences. The opportunities and challenges associated with each observation should be interpreted as the outcome of our interest in encouraging the IS discipline to move further along the trajectory of including the Design Sciences in mainstream IS research.

We are optimistic that the observations and arguments captured in the paper will be appealing to several allied disciplines. The central theme followed for the organization of the doctoral consortium as well as the analysis that followed (as reflected in this paper) views Design Sciences as a movement that affects not only the IS discipline but also several allied disciplines who must also contribute to its definition and participate in negotiating its jurisdiction claims. We hope that the paper and arguments contained therein will also serve the purpose of building bridges across these disciplines who are all interested in the field of study that we call the Sciences of Design.

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