Design Science Research in Information Syste

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Welcome

Welcome to the page on Design Science Research in Information Systems (IS). The intent of the pa provide design science researchers in IS as well as others interested in design science research with information on understanding, conducting, evaluating, and publishing design science research.

Introduction

This page is dedicated to design science research in Information Systems (IS). Design science rese another "lens" or set of analytical techniques and perspectives (complementing the Positivist and In perspectives) for performing research in IS. Design science research involves the design of novel o artifacts and the analysis of the use and/or performance of such artifacts to improve and understanc of aspects of Information Systems. Such artifacts include - but certainly are not limited to - algorit information retrieval), human/computer interfaces and system design methodologies or languages. science researchers can be found in many disciplines and fields, notably Engineering and Compute using a variety of approaches, methods and techniques. In Information Systems, following a numb a general shift in IS research away from technological to managerial and organizational issues, an i number of observers are calling for a return to an exploration of the "IT" that underlies all IS resea (Orlikowski and Iacono, 2001).

The page is organized as follows. We begin with a general overview of design science research, pr philosophical and epistemological underpinnings, and contrast design science research in IS with t positivist and qualitative research in IS. This is followed by a section on design science research m includes an extended discussion of a published example of design science research in IS. Through we hope to make concrete all phases of the design science research method: artifact design, constru analysis and evaluation. This is then followed by a number of resource sub-sections that relate to d research in general as well as to design science research in IS: citation lists, links to resources on th design science researchers, calls for papers and links to conferences, workshops, journals and com practice for IS design science research.

The goal is to provide the IS community with useful information on design science research both i of IS. The page contains numerous citations permitting the interested reader to easily access origin and examples of this unique and dynamic IS research paradigm.

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Overview of Design Science Research

Research

Drawing heavily from Kuhn (1996; first published in 1962) and Lakatos (1978), research can be ve defined as an *activity* that contributes to the *understanding* of a *phenomenon*. In the case of design research, all or part of the phenomenon may be *created* as opposed to naturally occurring. The *phe* typically a *set of behaviors of some entity*(ies) that is found *interesting* by the researcher or by a gr research community. *Understanding* in most western research communities is *knowledge that allo* of the behavior of some aspect of the phenomenon. The set of activities a research community con appropriate to the production of understanding (knowledge) are its research methods or techniques some research communities have been observed to have nearly universal agreement on the phenom interest and the research methods for investigating it; in this page we term these *paradigmatic* com Other research communities are bound into a nominal community by overlap in sets of phenomena and/or overlap in methods of investigation. We term these *pre-paradigmatic* or *multi-paradigmatic* communities. As of the writing of this page *Information Systems* is an excellent example of a multi community.

Design

Design means "to invent and bring into being" [Webster's Dictionary and Thesaurus, 1992]. Thus, with creating something new that does not exist in nature. The design of artifacts is an activity that carried out for centuries. This activity is also what distinguishes the professions from the sciences. architecture, business, education, law, and medicine, are all centrally concerned with the process o [Simon, 1996; first published in 1969]. However, in this century natural sciences almost drove out from professional school curricula in all professions, including business, with exceptions for mana science, computer science, and chemical engineering -- an activity that peaked two or three decade Second World War [Simon, 1996].

Simon sets out a prescription for schools of business (in which most IS departments are housed) th motivated this page to a considerable degree: ". . . The professional schools will reassume their . . . responsibilities just to the degree that they can discover a science of design, a body of intellectuall analytic, partly formalizable, partly empirical teachable doctrine about the design process . . . "

To bring the design activity into focus at an intellectual level, Simon [1996] makes a clear distincti "natural science" and "science of the artificial" (also known as design science):

A *natural science* is a body of knowledge about some class of things -- objects or phenomenon -- i (nature or society) that describes and explains how they behave and interact with each other. A *scie* *artificial*, on the other hand, is a body of knowledge about artificial (man made) objects and pheno designed to meet certain desired goals.

Simon further frames sciences of the artificial in terms of an *inner environment*, an *outer environm* *interface* between the two that meets certain desired goals. The outer environment is the total set o forces and effects that act on the artifact. The inner environment is the set of components that mak artifact and their relationships – the organization – of the artifact. The behavior of the artifact is co both its organization and its outer environment. The bringing-to-be of an artifact, components and organization, which interfaces in a desired manner with its outer environment, is the design activit is "structurally coupled" to its environment and many of the concepts of structural coupling that V and Maturana (1987) have developed for biological entities are applicable to designed artifacts.

In a perspective analogous to considering design as the crafting of an interface between inner and environment, design can be thought of as a mapping from function space - a functional requiremen a point in this multidimensional space - to attribute space, where an artifact satisfying the mapping point in that space (Takeda, et al, 1990). Design then, is knowledge in the form of techniques and r performing this mapping – the know-how for implementing an artifact that satisfies a set of functic requirements.

Design Research vs Design *Science* Research

Design science research in IS is a rapidly evolving field. In the relatively short period from the tim page was first initiated (late 2004) till now (9/2011) even the most commonly accepted name for th changed - from 'design research' (DR) to 'design science research' (DSR). As the DSR literature gai and depth researchers came to understand the term 'design research' had a long prior history as the design itself and designers - their methods, cognition and education. DR is a much broader area tha spanning all design fields, and more importantly, does not have the defining feature of DSR: learni building - artifact construction. IS Design Science researchers thus (in about 2005/6 as a scan of th will show) widely began to add the distinguishing word 'science' to the field designation. The distir frequently expressed is that DR is research *into* or *about* design whereas DSR is research *using des research method* or technique.

DSR when defined as learning through building is not unique to IS. The fields of education, health computer science and engineering also make extensive use of DSR. DSR in education - where curr learning programs are designed and empirically evaluated and in health care - where programs of t designed and empirically evaluated - share the DSRIS concern with rigorous evaluation and especi codification of design knowledge in design theories to a greater degree than do the technical discip computer science and engineering (Kuechler and Vaishnavi, 2011). More information on the histor especially in North America is available at the link immediately below.

A Short History of Design Science Research in Information Systems

� Can Design Be Research

The question this page intends to answer in the affirmative is: can design (i.e. artifact construction) considered an appropriate technique for conducting research into Information Systems? We will pu specific question in the next section. For the remainder of this section we discuss the question in th can design be research? – using as exemplars communities other than IS where the question of whe design is a valid research technique has for many years been a resounding Yes!

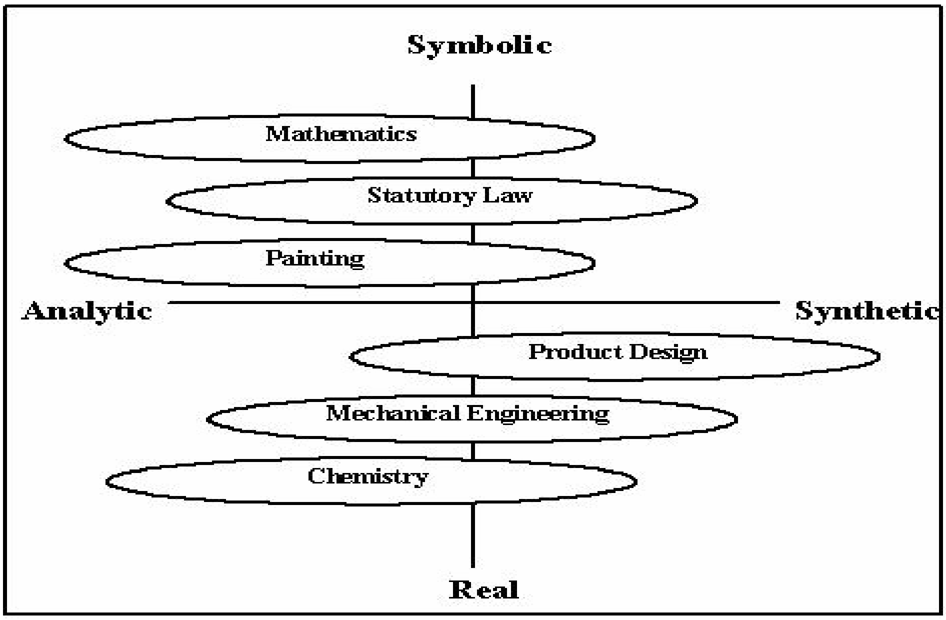

Figure 1. A Conceptual Map of Disciplines

Owen (1997) discusses the relation of design to research with reference to a conceptual map of dis((Figure 1) with two axes: Symbolic/Real and Analytic/Synthetic. The horizontal axis of the map pc disciplines according to their defining activities: disciplines on the left side of the map are more co exploration and *discovery*. Disciplines on the right side of the map are characterized more by inver *making*. The map's vertical division, the symbolic/real axis, characterizes the nature of the subjects the disciplines – the nature of the phenomena that concerns the research community. Both axes are no discipline is exclusively concerned with synthesis to the exclusion of analytic activities. Likewi is exclusively concerned with the real to the exclusion of the symbolic although the strong contrast axis between the physical science of chemistry (real) and the abstract discipline of mathematics (sy strongly and accurately indicated in the diagram.

The disciplines that lie predominantly on the synthetic side of the map are either design disciplines components of multi-paradigmatic disciplines. Design disciplines have a long history of building tl knowledge base through making – the construction of artifacts and the evaluation of artifact perfor following construction. Architecture is a strongly construction-oriented discipline with a history ex thousands of years. The architectural knowledge base consists of a pool of structural designs that e encourage the wide variety of human activities and has been accumulated largely through the post- observation of successful constructions (Alexander, 1964). Aeronautical engineering provides a mc example. From the Montigolfer balloon through WWI, the aeronautical engineering knowledge bas almost exclusively by analyzing the results of intuitively guided designs – experimentation at esser scale.��

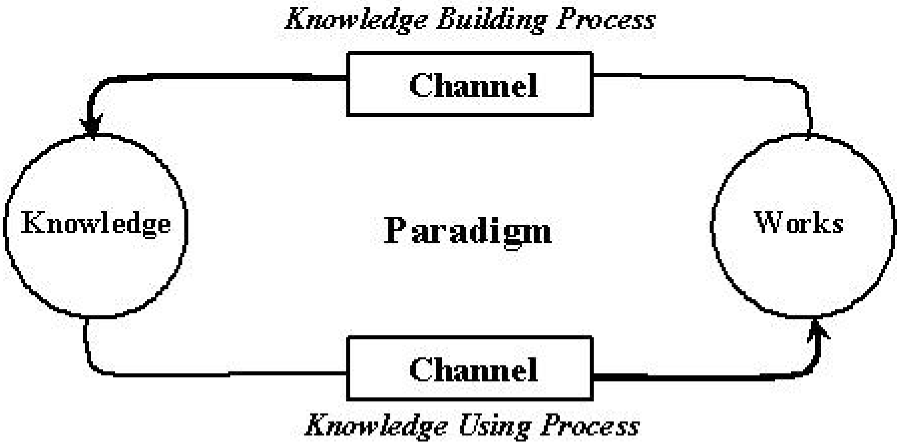

Figure 2. A General Model for Generating and Accumulating Knowledge

Owen (1997) further presents a general model for generating and accumulating knowledge (above) helpful in understanding design disciplines and the design science research process: "Knowledge is and accumulated through action. Doing something and judging the results is the general model . . . shown as a cycle in which knowledge is used to create works, and works are evaluated to build knc While knowledge building through construction is sometimes considered to lack rigor, the process unstructured. The *channels* in the diagram of the general model are the "systems of conventions an which the discipline operates." They embody the measures and values that have been empirically d "ways of knowing" as the discipline has matured. They may borrow from or emulate aspects of otł channels, but, in the end, they are special to the discipline and are products of its evolution."

Takeda, et al. (1990) have analyzed the reasoning that occurs in the course of a general design cycl Figure 3. This diagram can be interpreted as an elaboration of the *Knowledge Using Process* arrow In following the flow of creative effort through this diagram the types of new knowledge that arise activities and the reason that this knowledge is most readily found during a design effort will becor

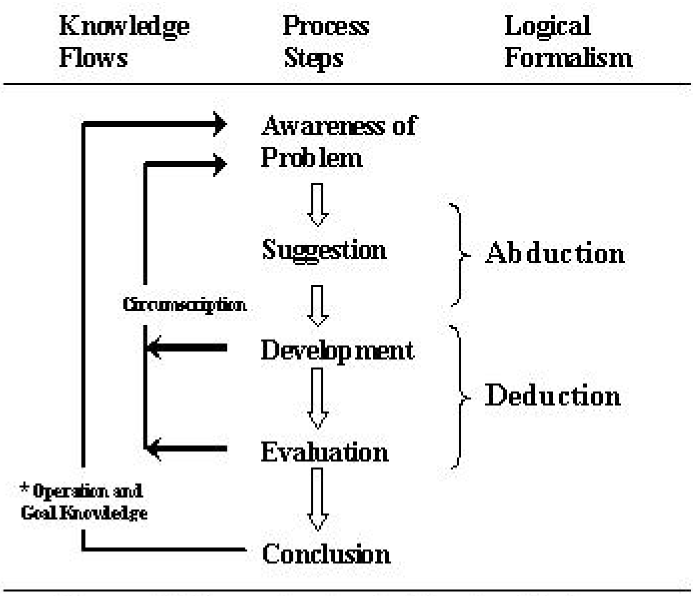

Figure 3. Reasoning in the Design Cycle

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

In this model all design begins with *Awareness of a problem*. Design science research is sometimes “Improvement Research” and this designation emphasizes the problem- solving/performance-impr of the activity. *Suggestions* for a problem solution are abductively drawn from the existing knowle base for the problem area (Pierce, 1931). An attempt at implementing an artifact according to the su solution is performed next. This stage is shown as *Development* in the diagram. Partially or fully su implementations are then *Evaluated* (according to the functional specification implicit or explicit i suggestion). *Development*, *Evaluation* and further *Suggestion* are frequently iteratively performed i of the research (design) effort. The basis of the iteration, the flow from partial completion of the cy *Awareness of the Problem,* is indicated by the *Circumscription* arrow. *Conclusion* indicates termina specific design project.

New knowledge production is indicated in Figure 3 by the arrows labeled *Circumscription* and *Op Goal Knowledge*.� The *Circumscription* process is especially important to understanding design s research because it generates *understanding that could only be gained from the specific act of cons* Circumscription is a formal logical method (McCarthy, 1980) that assumes that every fragment of valid only in certain situations. Further, the applicability of knowledge can only be determined thro detection and analysis of contradictions – in common language, the design science researcher *learn* when things *don't* work “according to theory." This happens many times not due to a misunderstan theory, but due to the necessarily incomplete nature of ANY knowledge base. The design process, interrupted and forced back to *Awareness of Problem* in this way, contributes valuable *constraint k* the understanding of the always-incomplete-theories that abductively motivated the original design

References on Design and Design Science Research

The Outputs of Design Science Research

Even within design science research communities there is lack of consensus as to the precise objec therefore the desired outputs - of design science research. In this page we present a broad perspecti explicates the types and levels of knowledge that *can* be derived from design science research whil judgment on whether a narrower goal of design science research should be held within any specific community.

March and Smith (1995) in a widely cited paper contrasting design science research with natural sc research, propose four general outputs for design science research: *constructs*, *models*, *methods,* an *instantiations*. *Constructs* are the conceptual vocabulary of a problem/solution domain. Constructs the conceptualization of the problem and are refined throughout the design cycle. Since a working (artifact) consists of a large number of entities and their relationships, the construct set for a design research experiment may be larger than the equivalent set for a descriptive (empirical) experiment.

A *model* is “a set of propositions or statements expressing relationships among constructs.” March identify models with *problem and solution statements*. They are proposals for how things are or sh Models differ from natural science theories primarily in intent: natural science has a traditional foc whereas design science research focuses more on (situated) utility. Thus a model is presented in ter does and a theory described in terms of construct relationships. However a theory can always be ex what can be done with the implicit knowledge and a set of entities and proposed relationships can a expressed as a theoretical statement of how or why the output occurs.

A *method* is a set of steps (an algorithm or guideline) used to perform a task. "Methods are goal dir for manipulating constructs so that the solution statement model is realized." Implicit in a design sc research method then is the problem and solution statement expressed in the construct vocabulary. natural science research, a method may well be the object of the research program in design scienc Since the axiology of design science research stresses problem solving, a more effective way of acc an end result – even or sometimes especially a familiar or previously achieved end result – is value

The final output from a design science research effort in March and Smith's explication is an *instan* "operationalizes constructs, models and methods."� It is the realization of the artifact in an enviro Emphasizing the proactive nature of design science research, they point out that an instantiation so precedes a complete articulation of the conceptual vocabulary and the models (or theories) that it e emphasize this further by referring to the aeronautical engineering example given earlier in this pag flew decades before a full understanding of how such flight was accomplished. And, it is unlikely t understanding would ever have occurred in the absence of the working artifacts.

Rossi and Sein (2003) and Purao (2002) in an ongoing collaborative effort to promote design scien have set forth their own list of design science research outputs. All but one of these can be mapped March and Smith's list. Their fifth output, *better theories*, is highly significant and merits inclusion general list of design science research outputs. Design science research can contribute to better the theory building) in at least two distinct ways, both of which may be interpreted as analogous to exp scientific investigation in the natural science sense. First, since the methodological construction of an object of theorizing for many communities (e.g. how to build more maintainable software), the c phase of a design science research effort can be an experimental proof of method or an experiment of method or both.

Second, the artifact can expose relationships between its elements. It is tautological to say that an a functions as it does because the relationships between its elements enable certain behaviors and co However if the relationships between artifact (or system) elements are less than fully understood a relationship is made more visible than previously during either the construction or evaluation phase artifact, then the understanding of the elements has been increased, potentially falsifying or elabora previously theorized relationships. (Theoretical relationships enter the design effort during the abdu reasoning phase of Figure 3). For some types of research, artifact construction is highly valued pre contribution to theory. Human-Computer Interface (HCI) researchers Carroll and Kellogg (1989) s HCI artifacts themselves are perhaps the most effective medium for theory development in HCI." W Widmeyer and El Sawy (1992) elaborate the theory building potential of design and construction in context of IS. Table 1 summarizes the outputs that can be obtained from a design science research e

	Output	Description
1	Constructs	The conceptual vocabulary of a domain
2	Models	A set of propositions or statements expressing relationships between constructs
3	Methods	A set of steps used to perform a task – how-to knowledge

4	Instantiations	The operationalization of constructs, models and methods.
5	Better theories	Artifact construction as analogous to experimental natural science, coupled with reflection and abstraction.

Table 1. The Outputs of Design Science Research

A different perspective on the output of design science research is developed in Purao (2002) follo
al. (2001). In Figure 4 the multiple outputs of design science research are classified by level of abs

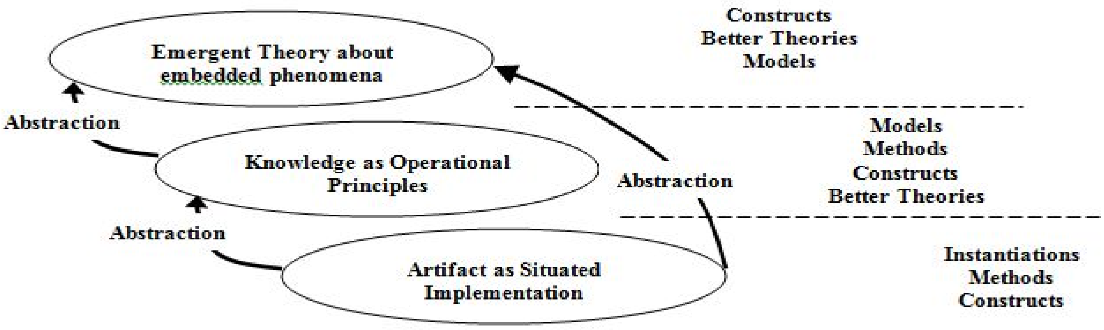

Figure 4. Outputs of Design Research
Purao (2002)

Explicitly the upper level of Figure 4 and implicitly the middle level, knowledge about operational
are theories about the emergent properties of the inner environment of the artifact (Simon, 1996). F
any complex artifact, at either level of abstraction, multiple principles may be invoked simultaneou
aspects of the artifacts behavior. In this sense, the behavior of the artifact in any single design scien
project is *overdetermined* (Carroll and Kellogg, 1989). This inevitable aspect of design science rese
consequences discussed further in the section on Philosophical Grounding of Design Science Rese

An example of community determined outputs

Precisely what is obtained from a design science research effort is determined by (1) the phase of r
which reflection and analysis focuses (from Figure 3) and (2) the level of abstraction to which the r
analysis generalize (from Figure 4). These factors in turn are strongly influenced by the community
the research.

To illustrate the different outputs that are commonly seen as the desired result for design science re consider the *same* artifact development as carried out by different IS research sub-communities: da software engineering, Human-Computer interface (HCI), decision sciences, and IS Cognitive Rese Cognitive Research Exchange -- IS CORE): the construction of a data visualization interface for cc queries against large relational databases. For all of the communities, the research is motivated by a *problem awareness*: that a better interface can be developed that will allow users to more quickly a obtain answers to questions about the performance of their business operations.

The theoretical impetus for the prospective improvement would vary between research communiti software engineering or database communities the motivation could be new knowledge of faster ac techniques or visual rendering techniques.� For the decision sciences community and the HCI anc research communities the impetus could be new research in reference disciplines on visual impacts and/or on decision-making. The resulting artifact would be quite similar for all communities, as wc construction mechanics – the computer languages used in development, the deployment platforms, the stages of development on which observation and reflection centered and the measures used to e resultant artifact (cf. Figure 3) would be considerably different for each community.� Table 2 lists communities that might construct a data visualization artifact, the primary perspective with which t view the artifact and the different knowledge that would emerge from the research effort as a result differing perspectives.

Community	Perspective	Knowledge Derived
HCI; IS CORE; Decision science	Artifact as experimental apparatus	What database visualization interfaces reveal about the cognition of complex data relationships
Database; Decision science Software engineering	Artifact as focused design principle exploration	Principles for the construction of data visualization interfaces
Database; Software engineering	Artifact as improved instance of tool.	A better data visualization interface for relational, business oriented databases.

Table 2. Design Science Research Perspectives and Outputs by Community

Some explications of design science research in IS have stated that the primary focus is always on artifact and how well it works rather than its component interactions i.e. *why* it works (Hevner, et a Other writers and our example present a broader view. The apparent contradiction may simply be i the net of *IS Research* is cast and the selection of sub-communities it is considered to contain.

Theory Development in Design Science Research

Another example of the rapid evolution of DSRIS is the recent attention directed to theory - both d per Walls, et al. (1992, 2004) and traditional explanatory/predictive theory - as a potential output o project. One of the seminal DSRIS papers, Nunamaker et al. (1991) alludes to theory and refineme an output from what they termed the "engineering model" of IS research. Shortly thereafter, Walls, presented their conception of design theory (ISDT), a prescriptive encoding of design knowledge a from a DSRIS project, and a number of widely cited IS papers subsequently made use of ISDT, for Kasper (1996) and Markus, Majchrzak and Gasser (2002). However, two influential papers subseq et al. 1992: March and Smith (1995) and Hevner, et al. (2004) did not explicitly mention theory an been interpreted by some in the field as suggesting that theory is **not** an output to be sought from D more recent papers including Gregor and Jones (2007), Kuechler and Vaishnavi (2008) and Arazy, Shapira (2010) explicitly mention theory, both prescriptive and explanatory, as DSR project output methods for developing such theory during the course of design science research. A link directly to recent papers concerned with theory in DSR is directly below.

References on Theory and Theory Development in DSR

General References on Design Science Research

The Philosophical Grounding of Design Science Research

Ontology is the study that describes the nature of reality: for example, what is real and what is not, fundamental and what is derivative?

Epistemology is the study that explores the nature of knowledge: for example, on what does know and how can we be certain of what we know?

Axiology is the study of values: what values does an individual or group hold and why?

The definitions of these terms are worth reviewing because although assumptions about reality, kn value underlie any intellectual endeavor, they are *implicit* most of the time for most people, includi researchers. Indeed, as historians and philosophers of science have noted, in "tightly" paradigmatic people may conduct research for an entire career without considering the philosophical implication passively received areas of interest and research methods (Kuhn, 1996; first published in 1962). It only in multi-paradigmatic or pre-paradigmatic communities - such as IS - that researchers are forc the most fundamental bases of the socially constructed realities (Berger and Luckman, 1966; Searl which they operate.

The contrasting ontological and epistemological assumptions implicit in natural science and social research approaches have been authoritatively explicated in a number of widely cited works (Bung and Lincoln, 1994). Gregg et al. (2001) add the meta-level assumptions of design science research term the Socio-technologist / developmentalist approach) to earlier work contrasting positivist and approaches to research. We have drawn from Gregg, et al. in compiling Table 3 which summarizes philosophical assumptions of those three "ways of knowing" and have added several insights from 40+ years of design science research experience. Our first addition is the stress on *iterative circum* Figure 3) and how this essential part of the design science research methodology iteratively determ reveals) the reality and the knowledge that emerge from the research effort. The second addition to row labeled Axiology – the study of values. We believe it is the shared valuing of what researchers in the pursuit of their efforts that binds them into a community. Certainly the self and community v their efforts and findings is a highly significant motivator for any researcher, and we were surprise little stress this topic has received in the literature, especially given the significant differences in w community values.

The metaphysical assumptions of design science research are unique.� First, neither the ontology, nor axiology of the paradigm is derivable from any other. Second, ontological and epistemological

shift in design science research as the project runs through circumscription cycles depicted in Figu
iteration is similar to but more radical than the hermeneutic processes used in some interpretive res

Design science research by definition changes the state-of-the-world through the introduction of nc Thus, design science researchers are comfortable with alternative world-states. The obvious contra positivist ontology where a single, given composite socio-technical system is the typical unit of an the problem statement is subject to revision as a design science research effort proceeds. However, world-states of the design science researcher are not the same as the multiple realities of the interp researcher: many if not most design science researchers believe in a single, stable underlying physi constrains the multiplicity of world-states. The abductive phase of design science research (Figure physical laws are tentatively composed into a configuration that will produce an artifact with the in problem solving functionality virtually demands a natural-science-like belief in a single, fixed grou

Epistemologically, the design science researcher knows that a piece of information is factual and k what that information means through the process of construction/circumscription. An artifact is cor behavior is the result of interactions between components. Descriptions of the interactions are info the degree the artifact behaves predictably the information is true. Its meaning is precisely the func enables in the composite system (artifact and user). What it means is what it does. The design scier is thus a pragmatist (Pierce, 1931). There is also a flavor of instrumentalism (Hendry, 2004) in des research.� The dependence on a predictably functioning artifact (instrument) gives design science epistemology that resembles that of natural-science research more closely than that of either positi interpretive research.

Axiologically, the design science researcher values creative manipulation and control of the enviro addition to (if not over) more traditional research values such as the pursuit of truth or understandi the design science researcher must have a far higher tolerance for ambiguity than is generally acce positivist research stance. As many authors have pointed out, the end result of a design science res may be very poorly understood and still be considered a success by the community (Hevner, et al, practical or functional addition to an area body of knowledge, codified and transmitted to the comr it can provide the basis for further exploration, may be all that is required of a successful project. I precisely in the exploration of "wicked problems" for which conflicting or sparse theoretical bases design science research excels (March and Smith, 1995; Carroll and Kellogg, 1989).�

Finally, the philosophical perspective of the design science researcher changes as progress is iterati through the phases of Figure 3. In some sense it is as if the design science researcher creates a reali constructive intervention, then reflectively becomes a positivist observer, recording the behavior o and comparing it to the predictions (theory) set out during the abductive phase. The observations a become the basis for new theorizing and a new abductive, interventionist cycle begins. In this sens science research is very similar to the action research methodology of the interpretive paradigm, hc time frame of design science research construction is enormously foreshortened relative to the soci interactions typical of action research.

Basic Belief	Research Perspective: Positivist	Interpretive	Design
Ontology	A single reality. Knowable, probabilistic	Multiple realities, socially constructed	Multiple, contextually situated alternative world-states. Socio-technologically enabled
Epistemology	Objective; dispassionate. Detached observer of truth	Subjective, i.e. values and knowledge emerge from the researcher-participant interaction.	*Knowing through making*: objectively constrained construction within a context. Iterative circumscription reveals meaning.
Methodology	Observation; quantitative, statistical	Participation; qualitative. Hermeneutical, dialectical.	Developmental. Measure artifactual impacts on the composite system.
Axiology: what is of value	Truth: universal and beautiful; prediction	Understanding: situated and description	Control; creation; progress (i.e. improvement); understanding

Table 3. Philosophical assumptions of three research perspectives

Bunge (1984) implies that design science research is most effective when its practitioners shift betv
pragmatic and critical realist perspectives, guided by a pragmatic assessment of progress in the des
Purao (2002) presents a very rich elaboration on the perspective shifts that accompany any iterative
His analysis is grounded in semiotics and describes in detail how "the design science researcher ar
interpretation (understanding) of the phenomenon and the design of the artifact simultaneously."

References on Philosophical Grounding of Design Science Research

Design Science Research Methodology (by Example)

In this section of the page the general method underlying design science research in its multiplicity
practiced variants is described, followed by a discussion of the method as used in a published exan
design science research.

The astute reader will recognize Figure 5, the general methodology for all design science research,
on Figure 3, reasoning in the design cycle. This is a logical and inevitable result of the fact that in d
research *knowing* (Figure 3) *is making* (Figure 5). To better focus on the process as a research *meth*
labeled Outputs has been substituted for the Logical Formalism column.

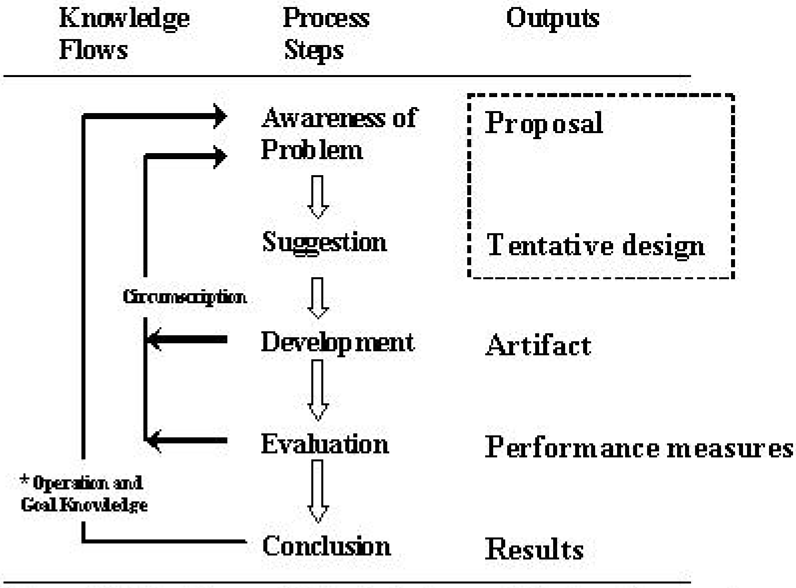

Figure 5. The General Methodology of Design Research

Note: there are many excellent descriptions (and diagrams) of the process of design science research in IS, cf. Hevner, et al., 2004; Purao, 2002; Gregg, et al., 2001;. March and Smith, 1995; Nunamaker, et al., 1991. We chose this diagram because it emphasizes the knowledge generation inherent in the method and because it originated in an analysis of the processes inherent in *any* design effort.

With reference to Figure 5 a typical design science research effort proceeds as follows.

Awareness of Problem: An awareness of an interesting problem may come from multiple sources: developments in industry or in a reference discipline. Reading in an allied discipline may also prov opportunity for application of new findings to the researcher's field. The output of this phase is a P formal or informal, for a new research effort.

Suggestion: The Suggestion phase follows immediately behind the proposal and is intimately conn as the dotted line around Proposal and Tentative Design (the output of the Suggestion phase) indica in any formal proposal for design science research such as one to be made to the NSF or an industr Tentative Design and likely the performance of a prototype based on that design would be an integ Proposal. Moreover, if after consideration of an interesting problem a Tentative Design does not pr the researcher, the idea (Proposal) will be set aside. Suggestion is an essentially creative step where functionality is envisioned based on a novel configuration of either existing or new and existing ele step has been criticized as introducing non-repeatability into the design science research method; h creativity is still a poorly understood cognitive process. However the step has necessary analogues methods; for example, in positivist research creativity is inherent in the leap from curiosity about a organizational phenomena to the development of appropriate constructs that operationalize the phe an appropriate research design for their measurement.

Development: The Tentative Design is implemented in this phase. The techniques for implementat course vary depending on the artifact to be constructed. An algorithm may require construction of a proof. An expert system embodying novel assumptions about human cognition in an area of interes software development, probably using a high-level package or tool. The implementation itself can pedestrian and need not involve novelty beyond the state-of-practice for the given artifact; the nove primarily in the design, not the construction of the artifact.

Evaluation: Once constructed, the artifact is evaluated according to criteria that are always implici frequently made explicit in the Proposal (Awareness of Problem phase). Deviations from expectati quantitative and qualitative are carefully noted and *must be tentatively explained*. That is, the evalu contains an analytic sub-phase in which hypotheses are made about the behavior of the artifact. Th exposes an epistemic fluidity that is in stark contrast to a strict interpretation of the positivist stanc equivalent point in positivist research, analysis either confirms or contradicts a hypothesis. Essenti some consideration of future work as may be indicated by experimental results, the research effort the design science researcher, by contrast, things are just getting interesting!� Rarely, in design sc research, are initial hypothesis concerning behavior completely borne out. Instead, the evaluation p and additional information gained in the construction and running of the artifact are brought togeth back to another round of Suggestion (cf. the circumscription arrows of Figures 3 and 5). The expla hypotheses, which are quite broad, are rarely discarded, but rather are modified to be in accord wit observations. This suggests a new design, frequently preceded by new library research in direction deviations from theoretical performance. (design science researchers seem to share Allen Newell's (from Cognitive Science) of theories as complex, robust nomological networks. This conception ha observed by philosophers of science in many communities (Lakatos, 1978), and working from it N that theories are not like clay pigeons, to be blasted to bits with the Popperian shotgun of falsificati they should be treated like doctoral students. One corrects them when they err, and is hopeful they their flawed behavior and go on to be ever more useful and productive (Newell, 1990).)

Conclusion: This phase is the finale of a specific research effort. Typically, it is the result of satisfi though there are still deviations in the behavior of the artifact from the (multiply) revised hypotheti predictions, the results are adjudged "good enough." Not only are the results of the effort consolida "written up" at this phase, but the knowledge gained in the effort is frequently categorized as either that have been learned and can be repeatably applied or behavior that can be repeatably invoked - c ends" – anomalous behavior that defies explanation and may well serve as the subject of further re

An Example of IS Design Science Research

The example we have chosen to add detail and concreteness to the discussion of design science res philosophy and method in Information Systems is one from the joint experience of the design scier page authors. We make only two claims for this research: (1) it is a reasonable example as it comfo encompasses all the points of the preceding discussion (2) since it is our research we are privy to a present a multitude of details that are rarely written up and available in journal publications. We de research, from conception to the first publication to be drawn from it, in phases corresponding to th diagrams 3 and 5.

Smart Objects: A Design Science Research Project

Awareness of Problem

In the mid-1980's one of the senior project participants, Vijay, began actively seeking to extend his from designing efficient data and file structures (a primarily computer science topic) to software er area with a significant IS component). In the course of a discussion with one of his colleagues at G University (GSU) he became aware of a situation that showed research promise:� development of computerized decision support system for nuclear reactors. Three Mile Island had brought national the problems associated with safe operation of a nuclear power plant, rule based decision support s current area of general IS interest, and the director of the research reactor at Georgia Tech was inte developing a system to support its operations.

A doctoral student (Gary) was brought into the project to begin a preliminary support system devel rule-based language Prolog. Within a few weeks it became apparent that a system to support the se thousand procedures found in a typical commercial power plant would be nearly impossible to dev and if developed would be literally impossible to maintain. The higher-level expert system develop packages available at the time (and currently) were more capable but still obviously inadequate. Th constructing and maintaining large expert systems was widely known at the time; however, the Pro project gave the research group significant insights they would not otherwise have had into the roo problem: continuously changing requirements and the complexity inherent in several thousand rule interlocking procedures. Out of detailed analysis of the failed pilot system emerged the first **aware** **problem** on which the research would focus: *how to construct and continuously maintain a suppor the operation of a complex, hierarchical, procedure driven environment*.�

Suggestion

There are many approaches to the problems of software system complexity and the research group them over a period of months. Some of the alternatives that were discarded were: development of a development methodology specifically focused on operation support systems, automation of the m function, and development of a high-level programming environment. New insights into the proble to emerge even as (and precisely because) potential solutions to the problem were considered. One was that the system complexity resided primarily in control of the system, that is, although the indi procedures could be modeled straightforwardly, the procedure which should take precedence (cont others and where the results of that procedure should be routed depended in a highly complex fashi and present states of multiple procedures. Essential to the development of the system was the effec of this complex control structure.

By this point Gary had decided to adopt the problem as his dissertation topic and under Vijay's dire extensive research into various mechanisms for modeling (describing in a precise, formal way) cor realization grew that they were in effect seeking to describe the *semantics* of the system, his readin focus especially on some of the techniques to emerge from the area of semantic modeling.

During the alternating cycles of discussion, reading and individual cogitation that characterize man science research efforts, several software engineering concepts were brought together with a final k yield the ultimately successful direction for the development. During one discussion Vijay realized control information for the system was knowledge, identical in form to the domain knowledge in th and could be modeled with rules, in the same way. However, since the execution of the individual p was independent of the control knowledge, the two types of rules could execute in different cycles, and greatly reducing the complexity of the overall system. Finally, the then relatively new concept orientation seemed the ideal approach to partitioning the total system knowledge into individual pr if each object were further partitioned into a domain knowledge and a control knowledge compone rules were stated in a high level English like syntax that was both executable and readable by doma leading to the concept of *smart objects* . . .

Awareness of Problem Redoux

As noted in the general discussion of the design science research method, any of its phases may be spontaneously revisited from any of the other phases. Especially in the early stages of a project, thi conceptual fluidity that can be disconcerting to practitioners of less dynamic paradigms. Though it retrospect to pinpoint exactly where in the process the change occurred, by the inception of the dev phase the problem statement had changed to a sub-goal implicit in the original problem statement: *effectively model operations support systems for complex, hierarchical, procedure driven environm* sort of "drilling down" into the problem or re-scoping the research at a more basic level occurs fre research, but is effectively part of the method in design science research.]

Development

Although development of a design science research artifact can be straightforward, that was not th smart objects. The construction was completely conceptual and involved the "discovery" through r thought and paper trials of the details of the novel entity that had been conceptualized at a high lev Suggestion phase, the "smart object."

For example: what (exactly) would the syntax be for the two types of rules, domain and control? H should the two rule evaluation cycles for each type of knowledge interleave? Should the two types be permitted to interact? If so, how? Should control rules have the ability to "write" or "rescind" d la Lisp? Or vice versa?

In a conceptual development such as this, the suggestion and construction phases blur because a su design decision *is* an output product. The final deliverable (from this initial development) was a co model consisting of: (1) a set of meta-level rules for implementing domain knowledge and control separately, but within a single structure, the "smart object" and (2) another set of meta-rules that d the domain and control knowledge, once "modeled" as smart objects, would be interpreted (a virtu executing the smart objects.)

Evaluation

In a sense evaluation takes place continuously in a design process (research or otherwise) since a l of "micro-evaluations" take place at every design detail decision. Each decision is followed by a "t experiment" in which that part of the design is mentally exercised by the designer. However for th this section we will describe the "formal" evaluation that occurred after the design had stabilized.

In order to test the conceptual design, various operating environments were modeled and "hand-ste through the execution rules to determine that logically correct system behavior occurred at appropr the simulation. The simulation that appeared in Gary's dissertation, the first publication to result fr research, was a grocery bagging "robot." This example had been popularized in a best-selling artifi intelligence textbook of the time and had the advantage of being a familiar logic test bed to many e evaluators of the artifact. Exponents of other IS research paradigms may find the evaluation criteri and wonder why, for example, modeling of the nuclear power plant operating environment was not choice. The answer is: resources; the modeling and hand testing of even the grocery-bagging exam several man-months. During the evaluation minor redesign of the artifact (the smart object concept occurred on several occasions, a common occurrence in design science research. By the end of the phase the smart object model had successfully completed simulation of numerous bagging exercis included complex control situations and was adjudged a success by the design team.

Conclusion

The finale for the first research effort involving Smart Objects was the codification of the problem design basis in prior work, the design itself, and the results of the evaluation effort in Gary's disser (Buchanan, 1991) The successful defense of the dissertation at GSU required careful consideration of the artifact and its performance by a committee made up primarily of other design science resea core concepts were considered to have substantial merit, and Gary and Vijay produced several con based on smart objects.

Epilogue

After Gary's graduation Vijay and Gary collaborated on a paper based on the research project and s IEEE Transactions on Data and Knowledge Engineering (TDKE). The paper was returned for subs revisions. At this point Gary's interest in the project waned, however a recently admitted GSU CIS student (Bill) found the concepts interesting enough to enter into the research group and continue t development effort. After four years, four conference papers on smart objects and related topics an revisions the TKDE paper was finally published as “A Data/Knowledge Paradigm for the Modeling of Operations Support Systems.” (Vaishnavi, Buchanan and Kuechler, 1997) By the time of accept objects had been through several additional design science research cycles, each focusing on the re different aspect of the original design, or a critical support function for its use-in-practice such as tl methodology developed for partitioning workflow information into smart objects.

References on Design Science Research Methodology

Design Science Research vs. Design

A significant and valid question posed frequently to design science researchers is: How is your rese from a design effort; what makes your work research and not simply state-of-practice design?

We propose that design science research is distinguished from design by the *production of interesti community) new knowledge*. In a typical *industry* design effort a new product (artifact) is produced cases, the more successful the project is considered to be, the less is learned. That is, it is generally produce a new product using state-of-practice application of state-of-practice techniques and readil components. In fact, most product design efforts in industry are preceded by many meetings desigr “engineer the risk out of” the design effort. The risks that are identified in such meetings are the “w how to do this yet” areas that are precisely the targets of design science research efforts. This is in r to diminish the creativity that is essential to any design effort. We merely wish to point out that des distinguished from design science research (within its community of interest) by the intellectual ris of unknowns in the proposed design which when successfully surmounted provide the new informa makes the effort research and assures its value.

Current Issues in Design [Science] Research

References on Understanding Design Science Research in the Context Information Systems Research

Citations on Design Science Research

- General References on Design Science Research
- References on Philosophical Grounding of Design Science Research
- References on Design Science Research Methodology
- References on Understanding Design Science Research in the Context of Information Systen

Resources for Design Science Researchers

Communities of Practice

- Design and Science: The site "discusses the relationship between Design and Science."
- Design Research Society (DRS) is a multi-disciplinary international learned society founded Members of DRS are drawn from diverse backgrounds ranging from fine art to engineering t

computing.� The aims of DRS include advancing the theory and practice of design and und design research and its relationship with its education and practice.� DRS is involved with s as organizing and sponsoring conferences, sponsoring e-mail discussion groups and a month newsletter.

- Design-Based Research Collective: The design research paradigm appears to have been purs education research (especially educational software and systems design). Although many of readings are the same (Schon, Simon, Alexander) the later traditions overlap a lot less. In edu traditionally been called *design experiments*, although this term is falling out of favor. The D Research Collective has been helping define the theory and practice of this research paradigr
- AIS Systems Analysis and Design Special Interest Group (SIGSAND) "AIS SIGSAND prov for AIS members: To discuss, debate, collaborate, develop, and promote issues pertaining to reference disciplines, theories, ontologies, methodologies and techniques, principles, new de practice, evaluation, quality control, management and pedagogy of systems requirements, an and implementation tasks and technologies In the business and organizational contexts. "
- AIS Special Interest Group on Philosophy and Epistemology in IS (SIGPhilosophy) "Curren observe a growing methodological debate in IS research. This debate appears to focus on epi especially research methods and techniques without relating to the broader issues of the phil science, epistemology and theory of knowledge. To overcome too narrow focus, it will be ne link the debates in IS research to questions about the very nature of research and science and role in general."
- Association for Information Systems (AIS) is "the premier global organization for academics in Information Systems."
- Association for Computing Machinery (ACM), founded in 1947, is "a major force in advanc of information technology professionals and students worldwide."
- IEEE Computer Society (IEEECS) is the "world's leading organization of computer professi nearly 100,000 members.
- IEEE Systems, Man, and Cybernetics Society (IEEESMC)
- American Society for Information Science and Technology
- INFORMS (Institute for Operations Research and the Management Sciences)
- The Information Institute "is an academe-industry consortium founded to further understanding of relationships between information science and technology."
- Informing Science Institute

Design And Design Science Research Centers / Labs

- Center for Design Research Center for Design Research at Stanford University, established i focuses on engineering design, design tool development, and design process research and pro collaboration between industry and academia.
- IIT Institute of Design The Institute of Design (ID) at Illinois Institute of Technology teaches human-centered design and focuses on the development of design methods and theories and demonstration of their utility.
- MIT Media Lab The Media Laboratory at MIT, established in 1985, emphasizes interdiscipli that combines disciplines such as cognition, electronic music, graphic design, holography wi computation and human-machine interfaces.
- The Palo Alto Research Center The Palo Alto Research Center (PARC), a subsidiary of Xero Corporation, conducts interdisciplinary design research in physical, computational, and socia
- Carnegie Mellon Software Engineering Institute (SEI) SEI is a federally funded research and center sponsored by the US Department of Defense devoted to making measured improveme software engineering capabilities.
- ISEing - Information Systems Evaluation and Integration Group is a center located at Brunel West London (U.K.) that is devoted to the conducting of basic and applied research on desig organizations and systems for actual operational conditions.

Other Research Centers / Labs

- Artificial Intelligence Lab
- Center for Research in Electronic Commerce
- Institute for Software Research������
- Network Convergence Laboratory�

Journals

- Journal of Design Research an electronic journal established in 2001, is a general design rese that is devoted to integrated studies of social sciences and design disciplines emphasizing hu as a central issue of design

���� The following journals tend to be receptive to design research in information systems:

- ACM Computing Surveys

ACM Transactions on:

- Computer-Human Interaction
- Database Systems
- Information and System Security
- Information Systems
- Internet Technology
- Management Information Systems
- Software Engineering and Methodology

AIS Journals and Transactions:

- AIS Transactions on Human-Computer Interaction
- Journal of the Association for Information Systems
- Management Informations Systems Quarterly

IEEE Magazines

- Computer
- Computer Graphics
- Intelligent Systems
- Internet Computing
- IT Professional
- MultiMedia
- Pervasive Computing
- Security & Privacy
- Software

IEEE Transactions On

- Computers
- Knowledge and Data Engineering
- Learning Technologies
- Mobile Computing
- Multimedia
- Pattern Analysis & Machine Intelligence

- Services Computing
- Software Engineering
- Systems, Man, Cybernetics
- Visualizations and Computer Graphics
- IEEE/ACM Transactions on Networking

Other Journals

- AI for Engineering Design, Analysis and Manufacturing (AIEDAM) is a journal intended to audiences: engineers and designers who see AI technologies as powerful means for solving c engineering problems; and researchers in AI and Computer Science who are interested in app AI and in the theoretical issues that arise from such applications.
- Business and Information Systems Engineering
- Communications of the AIS (CAIS)
- Communications of the ACM (CACM)
- Data & Knowledge Engineering
- Decision Support Systems
- Electronic Markets - The International Journal on Networked Business: The journal offers a high quality research from diverse methodological directions in order to lead further and asse developments. This not only includes quantitative empirical research but also qualitative and **science** contributions.
- Information Sciences
- Information Systems
- Information Systems Frontiers
- Information Systems Research
- Information Technology & Management
- Information Technology & Systems eJournal welcomes abstracts of working papers, forthcom and recently published articles focusing on the "**design science**" perspective on information research.
- Informing Science: The International Journal of an Emerging Transdiscipline
- INFORMS Journal on Computing
- Journal of the American Society for Information Science and Technology
- Journal of Database Management
- Journal of Electronic Commerce Research
- Journal of Management Information Systems
- Journal of Systems and Software
- Requirements Engineering Journal
- VLDB Journal

� Conferences

- Americas Conference on Information Systems (AMCIS)
- Hawaii International Conference on System Sciences (HICSS)
- International Conference on Design Science Research in Information Systems and Technolog (DESRIST)
- International Conference on Information Systems (ICIS)
- Workshop on Information Technologies and Systems (WITS)

Other Resources

- AI in Design Webliography is a a collection of information at Worcester Polytechnic Institute Design, Knowledge Based Design, Intelligent CAD, Computational Approaches to Design, a Theory and Methodology.

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Citation Information

The complete citation for this work is as follows:

Vaishnavi, V. and Kuechler, W. (2004). “Design Science Research in Information Systems” Januar last updated November 11, 2012. URL: http://www.desrist.org/design-research-in-information-syst

This page was last updated on November 11, 2012