The Role of Theory and Theorising in Design Science Research

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Abstract:

The literature on Design Science (or Design Research) has been mixed on the inclusion, form, and role of theory and theorising in Design Science. Some authors have explicitly excluded theory development and testing from Design Science, leaving them to the Natural and Social/Behavioural Sciences. Others propose including theory development and testing as part of Design Science. Others propose some ideas for the content of IS Design Theories, although more detailed and clear concepts would be helpful. This paper discusses the need and role for theory in Design Science. It further proposes some ideas for standards for the form and level of detail needed for theories in Design Science. Finally it develops a framework of activities for the interaction of Design Science with research in other scientific paradigms.

1. Introduction

Theory and theorising have long played an important role in the evolution and practice of science. Theory embodies statements of the knowledge that has been developed by humanity in a form that has both use in the practical world where human beings act based on their knowledge (partly learned from theories) and in the theoretical world where researchers validate or refute old knowledge and build new knowledge in the form of theories. As a collaborative practice of creating and validating knowledge, science and the scientists who practice it rely on the clear and succinct statements of theory, possibly/often together with attendant explanations of theory.

Theory and theorising play key roles in both the natural and the social/behavioural sciences. The natural sciences have advanced primarily through the extensive development and testing of theory, largely through positivist methods. The social and behavioural sciences have also advanced through the development and testing of theory. However, the methods for social science have varied from positivist through interpretivist methods due to the complex and subjective nature of (most of) social reality. The subjective and complex nature of social reality and the interpretivist methods used make theory testing more difficult, but building and testing of theories are still important goals in social research. Both natural and social sciences are empirical in nature, with theory as the primary product.

In the Sciences of the Artificial (1996), Herbert Simon identified the need for developing various Design Sciences. A Design Science is an inventive or creative, problem solving activity, one in which new technologies are the primary products.

Design Science research presents a large opportunity to increase the relevance of IS research (Nunamaker, et al, 1991, March and Smith, 1995, Rossi and Sein, 2003, Hevner et al, 2004). It is argued here that there is a strong need to increase the amount

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and improve the practice of this kind of research. This paper contributes to efforts in that vein.

In contrast to physical and social sciences, in Design Science (or Design Research) in the Information Systems field, the development and testing of theory has been excluded by some authors and left in the domain of natural and social sciences. As Vaishnavi and Kuechler (2004) point out, "Even within design research communities there is lack of consensus as to the precise objective – and therefore the desired outputs – of design research."

This paper contends that, like other scientific research paradigms, theory should be a primary output and that theory and theorising need to play a central role in the advancement of Design Science Research in IS (as well as in other fields). This paper expands on prior IS Design Science literature by discussing the role of theory and the activity of theorising in Design Science Research as it is currently – and more importantly how it should be – practiced in IS.

The next section reviews how other authors on Design Science have treated theory and theorising. Following that, section three addresses the important role of theory in distinguishing design science from design practice. Section four then makes a case for why theory and theorising should be a key part of Design Science. Section five then proposes a form for design theory, which we call a utility theory, and describes some standards for the required detail. Section six describes how utility theories are created and evolved during the course of Design Science Research. Section seven then presents an activity framework for integrating Design Science (or Technology Invention/Design as its key activity) with Technology Evaluation and Problem Diagnosis activities before the final section, which summarises the paper.

2. Design Science Literature on Theory and Theorising

Design Science has its roots in engineering and other applied sciences. An important foundation is Herbert Simon's conceptualisation in The Sciences of the Artificial (first published in 1969, third edition in 1996). Simon (1996) noted that "Schools of architecture, business, education, law, and medicine, are all centrally concerned with the process of design." Clearly this includes the 'school' or entire field of Information Systems. The other 'schools' cited above provide potential exemplars (or reference disciplines) upon which the IS field could (and often does) draw guidance and inspiration. Simon goes on to note that such schools can achieve their purpose (and establish their credibility) "to the degree that they can discover a science of design, a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process." In a sense, this sets out an important agenda for IS research.

Less commonly acknowledged in Design Science, but very relevant, is Peter Checkland's conceptualisation of Human Activity Systems in Soft Systems Methodology (SSM) (Checkland and Scholes, 1999), which are systems of or supporting human activity and the human purposes for which they exist. Information Systems and the work processes that they support are examples of human activity systems. Parts or all of SSM are widely used to guide Information Systems Development.

Nunamaker, et al (1991), who did not draw upon Simon as a reference, wrote a seminal paper in design science, even though they didn't call it that (instead calling it the "engineering approach"). Their focus was on justifying system development (a subset of design science) as an IS research method. Other kinds of designed artifacts (such as system development methods) were excluded (Venable and Travis, 1999).

Theory and theorising are important ingredients in the Nunamaker et al (1991) approach to Design Science. They explicitly recognised that complementary IS research methods are needed and asserted that “an integrated multi-dimensional and multimethodological approach will generate fruitful IS research results” (p. 89). They developed a framework of a “Multimethodological Approach to IS Research” (figure 2, p. 94) incorporating four complementary forms of research: theory building, systems development, observation, and experimentation, all of which inform each other. The latter two activities are forms of evaluation and fit the last stage of what they called the “concept–development–impact” model of a research life cycle. They viewed development as a bridge between technological research at the concept stage and social research at the impact stage. The theory building activity included “development of new ideas and concepts, and construction of conceptual frameworks, new methods, or models” (p. 94) as well as theories. However, theories were thought to be too general to give much practical relevance. However, analysis of existing theories might suggest new research hypotheses and guide evaluation. They also noted that difficulties encountered in system development activities might lead to modification of the concepts or theories from which IS are derived (p. 95).

Roles for theory and theorising also appear in the System Development Research Process that Nunamaker, et al (1991) proposed (figure 3, page 98). Their process is composed of five stages or activities (with backtracking) including: (1) construct a conceptual framework, (2) develop a system architecture, (3) analyse and design the system, (4) build the (prototype) system, and (5) observe and evaluate the system. While most of these activities are specific to IS rather than other kinds of designed technological artifacts, the first and last steps are relevant to theory and theorising. The first stage includes “State a meaningful research question” (figure 3, p 98), which is presumably based on theory, and “Study relevant reference disciplines for new approaches and ideas” (p. 98), which is also based on theory. Their detailed description of the first step includes four different types of theory building efforts: “(a) declare the ‘truth’”, “(b) formulate a concept (i.e. a framework)”, “(c) construct a method”, and “(d) develop a theory” (p. 99). The last stage of their System Development Research Process explicitly includes “Develop new theories/models based on the observation and experimentation of the system’s usage” (p. 98, emphasis added).

Walls et al (1992), who did not reference Nunamaker et al (1991), addressed Simon’s call in the information systems field and directly addressed the role of theory and theorising in Design Science Research. They proposed that an Information Systems Design Theory (ISDT) should “be a prescriptive theory which integrates normative and descriptive theories into design paths intended to produce more effective information systems.” (p. 36). They give seven characteristics that distinguish design theories (pp. 40-41)

1. “Design theories must deal with goals as contingencies. …
2. A design theory can never involve pure explanation or prediction. …
3. Design theories are prescriptive. …
4. Design theories are composite theories which encompass kernel theories from natural science, social science and mathematics. …

5. While explanatory theories tell ‘what is’, predictive theories tell ‘what will be’, and normative theories tell ‘what should be’, design theories tell ‘how to/ because.’ …
6. Design theories show how explanatory, predictive, or normative theories can be put to practical use. …
7. Design theories are theories of procedural rationality.” (Walls et al, 1992, pp. 40-41)

Walls et al (1992) argue that an ISDT would need to address both the design product and the design process used to derive the design product. An ISDT would have seven components, four of which relate to the design product and three of which relate to the design process.

The four components of an ISDT about the design product according to Walls et al (1992) are (1) meta-requirements, (2) meta-design, (3) kernel theories, and (4) testable design product hypotheses. Meta-requirements concern the class of goals to be addressed by the application/use of the design product. They are called meta-requirements rather than just requirements because they address a generalised class of goals rather than particular, situated goals (e.g. in some particular organisation at some point in time). Meta-design concerns the design of design product and “describe the class of artifacts hypothesised to meet the meta-requirements. It is called meta-design rather than just design because the design product is not a particular instantiation, but a general approach to be used in particular occurrences of the class of goals in the meta-requirements. Kernel theories are drawn from natural or social sciences and “govern design requirements.” (p. 42). Testable design process hypotheses are falsifiable statements (which can be proven false through, typically positivist, research) asserting that (instantiations of) the meta-design is able to satisfy (instances of) the meta-requirements.

The three final components of an ISDT according to Walls et al (1992), which are about the design process, are (5) design method, (6) kernel theories, and (7) testable design process hypotheses. The design method “describes procedure(s) for artifact construction.” (p. 43). While the word ‘construction’ is used, they make clear that “design commences immediately after problem identification and terminates when the customer signs off on the system”, which indicates a very broad coverage of activities used to develop a particular, situated application of the meta-design to a particular problem, not just the narrower meanings of ‘design’ (abstract in nature) or ‘construction’ (real or concrete in nature). Kernel theories are drawn from natural or social sciences, as above, but apply to the design method. Testable design process hypotheses are again falsifiable statements, but ones that assert that the (use of) the design method will arrive at a (proper) (instantiation of) the meta-design.

March and Smith (1995) also took up Simon’s gauntlet for the IS/IT field. However, they did not reference either Nunamaker et al (1991) or Walls et al (1992). They noted that in its practice, Design Science needs to undertake two main processes: build and evaluate. The build process recognises the important step from design (which is commonly considered to be an abstract activity) to construction, which is a physical (in at least some sense) realisation (or implementation) of the design. The build activity results in one or more design artifacts, such as a model, method, or instantiation. It also produces constructs, which are concepts that form the language to describe both the artifact(s) and other relevant phenomena, such as those tasks and situations that form the context of the purpose for the creation of the artifact(s). The evaluate activity concerns determining whether (or not) the design artifacts produced are effective in achieving their purpose, provide value, are not overly expensive, are useful, have utility, and/or produce adverse or unwanted side-effects. These two processes are conducted in tandem in a cycle.

March and Smith (1995) further proposed two other activities – theorise and justify. These are seen as the separate province of natural (presumably including social and behavioural) sciences. This can be illustrated with several quotes. "Natural science is concerned with explaining how and why things are. Design science is concerned with 'devising artifacts to attain goals'." (p. 253, quoting Simon, 2nd edition, p. 133) "Rather than producing general theoretical knowledge, design scientists produce and apply knowledge of tasks or situations in order to create effective artifacts." (p. 253) "Rather than posing theories, design scientists strive to create models, methods, and implementations that are innovative and valuable." (p. 254) "Theorizing and justifying have natural science intent." (p. 256) "In our framework, however, the concern of models is utility, not truth (the concern of theories is truth, as discussed below)." (p. 256)

For March and Smith then, theory is *not* part of Design Science; theories are "deep, principled explanations of phenomena" (p. 253), which are developed by Natural Science. In summary, according to March and Smith (1995), while design artifacts are evaluated for their utility in Design Science, explaining that utility (or lack of it) through theorising and justification is the province of Natural Science.

Venable and Travis (1999) built on the work of Nunamaker et al (1991) (but not on Walls et al, 1992 or March and Smith, 1995), supporting the key role of theory building, but extending Nunamaker et al's notion of a Computer-Based Information System as the designed artifact to include IS Development Methods, Tools, and Techniques as kinds of systems or designed artifacts that are theorised about, developed, and evaluated. Venable and Travis (1991) also modified the Multimethodological IS Research Framework in Nunamaker et al (1991) to substitute "*In Situ* Investigation" for "observation" and include Action Research as a method for *In Situ* Investigation.

Markus et al (2002), furthering the work by Walls et al (1992), further develop the idea of a design theory (or ISDT in Walls et al, 1992). A design theory would include concepts (cf. constructs in March and Smith, 1995) of "a particular class of user requirements" (cf. "meta-requirements" in Walls et al, 1992), a "type of system solution" (to the problem) (cf. "meta-design" in Walls et al, 1992), and "effective development practices" (cf. "design method" in Wall et al (1992) for achieving the development and implementation of a particular solution to a particular (situated) problem. These theories themselves would then be evaluated for their truthfulness in representing the utility in the "type of system solution" in solving the problems inherent in the "particular class of user requirements."

Providing another contrasting perspective to March and Smith, Rossi and Sein (2003, in acknowledged collaboration with Purao) added "better theories" (p. 5) as a desired product and "theorise" (p. 6) as a step in Design (Science) Research. They do not separate out Design Science activities from those of Natural Science, instead integrating theory and theorising.

In addition to "better theories", the other products proposed by Rossi and Sein (2003) were Conceptual Designs (similar, but somewhat different from constructs), Methods, Models and Systems (similar to instantiations). However, the "better theories" that they proposed seem to be systems of concepts and relationships of the design artefacts themselves, rather than "explaining how and why things are" (March and Smith, 1995, p. 253).

Rossi and Sein (2003) propose five steps in Design (Science) Research: identify a need, build, evaluate, learn, and theorize. Identifying a need includes identifying deficiencies in current (information) systems and problems in the field, as well as searching for prior, relevant research. During evaluation, Rossi and Sein (and Purao, 2003) propose both internal and external criteria. Among the internal criteria is "Match between the artifact and the 'abstract idea'. How well does the artifact embody the abstract idea that is being researched?" (p. 8). This concerns the constructs or concepts and how faithfully they are implemented in the models, methods, and instantiations. Among the external criteria is "Advancement of design theory: Is the abstracted idea generalisable to other contexts or at least advance our understanding of other design contexts?" (p. 9). This proposes that goals for good design theory would include generalisability of the artefacts and the utility of the design artefacts in other problem contexts.

The recent paper by Hevner et al (2004) in MIS Quarterly represents the most recent and accepted statement of the IS field's conception of Design Science in IS research. The authors draw on the earlier work of March and Smith (1995) and others to develop an overall IS Research Framework as well as guidelines for the conduct and reporting of Design Science research.

The role of theory in Design Science as described in Hevner et al (2004) is unclear as they do not make a strong statement one way or the other. On one hand, the paper subscribes to the duality of Design Science and Natural (or Behavioural) Science as in March and Smith (1995), e.g. noting that "truth (justified theory) and utility (artifacts that are effective) are two sides of the same coin and that scientific research should be evaluated in light of its practical implications" (p. 77). Further, in their IS Research Framework (figure 2, p.80), the knowledge foundations used to develop new technologies distinguish theories from frameworks, instruments, constructs, models, methods, and instantiations. They further note that "Truth informs design and utility informs theory." (p.80). On the other hand, Hevner et al also accommodate aspects of Design Theory as in Markus et al (2002) and Walls et al (1992), e.g. stating that "their [design artifacts'] creation relies on existing kernel theories that are applied, tested, modified, and extended through the experience, creativity, intuition, and problem solving capabilities of the researcher (Markus et al 2002, Walls et al 1992)" (p. 76) and "Such theories prescribe 'effective development practices' (methods) and 'a type of system solution' (instantiation) for 'a particular class of user requirements' (models) (Markus et al. 2002, p. 180). Such prescriptive theories must be evaluated with respect to the utility provided for the class of problems addressed." (p. 77).

From a process point of view, Hevner et al (2004) is also ambiguous. The IS Research Framework (p. 80) that they present combines the Theorise (theory) and Build (artifacts) activities of March and Smith (1995) into a single Develop/Build activity and the Justify (theory) and Evaluate (artifacts) activities (March and Smith, 1995) into a single Justify/Evaluate activity. Thus, they "combine behavioural-science and design-science paradigms." (Hevner et al, 2004, p. 79). The merged Develop/Build and Justify/Evaluate activities then constitute IS Research and produce both artifacts for "application in the appropriate environment" (outcomes of build and evaluate) and "additions to the knowledge base" (outcomes of develop and justify) (Hevner et al, 2004, figure 2, p. 80).

Hevner et al (2004) then go on to provide seven guidelines for Design Science in IS Research, which can be summarised as follows:

(1) Design as an Artifact – An identifiable and viable design artifact, as in March and Smith (1995), must be produced.
(2) Problem Relevance – The design must address a relevant and important problem.
(3) Design Evaluation – The utility, quality, and efficacy of the design artifact must be rigourously evaluated.
(4) Research Contributions – The contribution must be clear and verifiable. Contributions are seen to arise out of the novelty, generality, and significance of the designed artifact. Contributions include the design artifacts themselves, new foundations (constructs, models, methods, and instantiations), and new [evaluation] methodologies.
(5) Research Rigour – Research methods must be rigorously applied.
(6) Design as a Search Process – Research must be conducted with knowledge of other, competing approaches and should approach the process as a cyclical problem solving process, in which solutions are tested against each other and against their efficacy for solving the full problem.
(7) Communication of the Research – Presentation of results needs to address both the rigour requirements of the academic audience and the relevance requirements of the professional (e.g. managerial) audience.

When looking for the role of theory and theorising in the Hevner et al (2004) process description summarised above, new or revised theory is not mentioned as a Research Contribution. However, as part of Research Rigour, they do mention that the researcher needs to be skilled in the "selection of appropriate means to justify the theory or evaluate the artifact." (p. 88).

The Design Research web pages (Vaishnavi and Kuechler, 2004), a portion of the ISWorld website, review much of the research above and provide their own perspective on Design (Science) Research. The website implicitly recognises a role for theory and theorising in Design Research, but does not make its own strong statement. In particular, it does not pick up the idea of a IS Design Theory (Walls et al, 1992, Markus et al, 2002).

When reviewing March and Smith's (1995) research products, they note:

> "Models differ from natural science theories primarily in intent: natural science has a traditional focus on truth whereas design research focuses more on (situated) utility. Thus a model is presented in terms of what it does and a theory described in terms of construct relationships. However a theory can always be extrapolated to what can be done with the implicit knowledge and a set of entities and proposed relationships can always be expressed as a theoretical statement of how or why the output occurs." (Vaishnavi and Kuechler, 2004).

Thus, the authors note the roughly interchangeable nature of models and theories (as forms for representing knowledge). However, the authors go further to describe different levels of abstraction in the knowledge either implicit or explicit as outputs of design research (Vaishnavi and Kuechler, 2004, figure 4, reproduced below). In particular, they note that "better theories" (not to mention "constructs" and "models") are present both at the middle level of "knowledge as operational principles" and the higher abstraction level of "emergent theory about embedded phenomena".

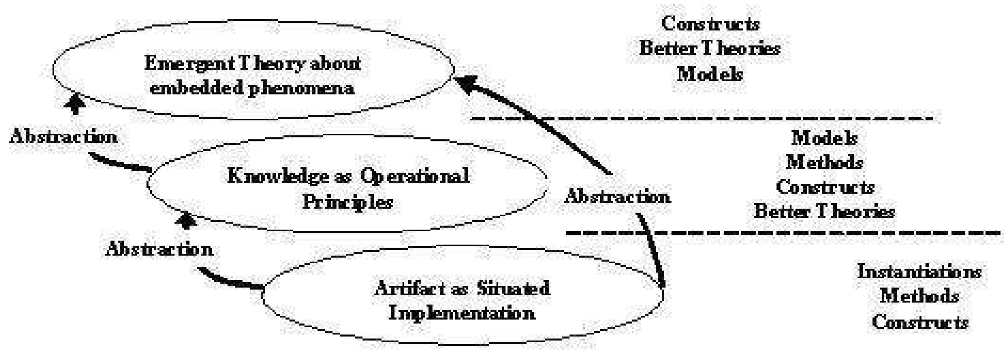

Figure 4. Outputs of Design Research

Figure 1: [Figure 4 above reproduced from Vaishnavi and Kuechler, 2004]

Venable (2006) further develops a Framework of Design Science Research Activities based on Nunamaker et al (1991) and Venable and Travis (1999). As in Nunamaker et al (1991) and Venable and Travis (1999), the framework includes "Theory Building" as a key activity, although the subject and content of that activity are much refined and consistent with the description in sections 5 and 6 of this paper.

However, the framework in Venable (2006) substitutes "Solution Technology Invention" for "Systems Development" (Nunamaker et al, 1991, Venable and Travis, 1999), which stresses that the "design product" and "meta-design" (Walls et al, 1992), the "design artifacts" of "models" and "instantiations" (March and Smith, 1995, Rossi and Sein, 2003, Hevner et al, 2004), and, indeed, the "IT artifacts" (Orlikowski and Iacono, 2001, Weber, 2003) that are of interest in the IS/IT field are not limited to computer-based information systems (although this may be a natural emphasis). There are many *designed* artifacts (or solution technologies) in the IS/IT field beyond computer-based IS. The author asserts that Design Science should address these as well. Solution technologies that are relevant in the IS/IT field include IS development methods, techniques, and tools, IS planning methods, IS management methods, IS/IT security and risk management practices, algorithms for computer processing, such as database processing, and many others, all of which are designed purposefully to address human and organisational problems and all of which must be adapted or re-designed when addressing particular, situated problems. This assertion is somewhat in line with Hevner et al (2004), who note interest in "organizations, policies, and work practices as designed artifacts". Indeed, Boland and Collopy (2004) deal with Management as Designing, which includes IS/IT management as well.

The framework in Venable (2006) also substitutes "Naturalistic Evaluation" for "Observation" (Nunamaker et al, 1991) and "*In Situ* Investigation" (Venable and Travis, 1999) as well as substituting "Artificial Evaluation" for "Experimentation" (Nunamaker et al, 1991, Venable and Travis, 1999). These stress the differences between the alternative means of evaluating solution technologies and their attendant design theories. These activities are consistent with the notion in Markus et al (2002) of evaluating the truthfulness of the utility of the design artifact as espoused in the design theory.

Gregor (forthcoming) investigates the nature of theory in the Information Systems field broadly, but including Design Science. The paper discusses issues of causality, explanation, prediction, and generalisation and identifies four goals of theories: analysis (describing what is, but without causal relationships), explanation (describing how, why, and when phenomena happen), prediction (stating what will happen if causal pre-conditions are met), and prescription (describing 'how to do' – or how one *should* do – something, especially building an IS). Gregor further develops a classification of five different types of theory based on those those goals: (Type I) theory for analysing, (Type II) theory for explaining, (Type III) theory for predicting, (Type IV) theory for explaining and predicting (EP), and (Type V) theory for design and action. Type V theory is prescriptive in nature. Interestingly, Gregor only applies this Type V theory to theory "used in the development of IS", is to the "design method" (Walls et al, 1992), but not to the solution technology or "meta-design" (Walls et al, 1992) itself.

Each of the five theory types are described by Gregor (forthcoming) in terms of four components of theories common to all five theory types: (1) means of representation, (2) constructs, (3) statements of relationship, and (4) scope. Three further theory components apply to only some of the five theory types: (5) causal explanations, (6) testable propositions (hypotheses), and (7) prescriptive statements.

Theories of Type IV (Theory for Explaining and Predicting, or EP Theory) and Type V (Theory for Design and Action) (Gregor, forthcoming) are of the most interest to us here. Design theories could be said to predict improvement (or meeting of meta-requirements) via the application of a particular solution technology (or meta-design). As noted above, according to Walls et al (1992), design theories should also include a design method. Explanation is also important, although how this comes into a design theory is not well described in Walls et al (1992). One would assume from the prescriptive nature of Type V theory that it would correspond best to a prescriptive IS Design Theory (ISDT) as in Walls et al (1992). However, there seems to be an inconsistency between the two in that Type V theory (as described by Gregor) does not address prescription of the meta-design to meet the meta-requirements, only of the design method to instantiate the meta-design in a particular problematic situation.

3. Design Science (Research) vs Design Practice – The Role of Theory

An important issue and one that has confronted all of the above authors is the issue of practice vs research. The issue of (and justification for) how system development can be research rather than just practice drove Nunamaker et al (1991) in the first place.

Vaishnavi and Kuechler (2004) put the issue into words as these questions: "How is your research different from a design effort; what makes your work research and not simply state-of-practice design?" Vaishnavi & Kuechler (2004). They answered the question with this assertion: "We propose that design research is distinguished from design by the production of interesting (to a community) new knowledge." Vaishnavi & Kuechler (2004). March and Smith (1995, p. 252) echo this when they contrast "knowledge-producing [design science] and knowledge using [design practice] activities."

Hevner et al (2004, p. 81) provide more clarity and contrast Design Science Research, which "addresses important unsolved problems in unique or innovative ways or solved problems in more effective or efficient ways" as opposed to routine design, which "is the application of existing knowledge to organizational problems." They further note that a key differentiator is that Design Science Research clearly identify its "contribution to the archival knowledge base of foundations and methodologies." (p. 81).

This differentiation is implicit in the way Walls et al (1992) distinguish "meta-requirements" and "meta-design" (research outcomes) from ordinary requirements and design (practice outcomes) by the way they describe a *class* of goals or a *class* of artifacts.

We agree with these perspectives and would further distinguish Design Science as "Technology Invention" and Design Practice as "Technology Application".

Another perspective considers both design science and design practice as problem solving activities. From that perspective, we can distinguish design practice as problem solving that is related to a particular, situated problem (or group of related problems) with particular stakeholders. Design Science Research on the other hand should be related to a generalised (or abstracted), type, kind, or class of problems that are relevant to typical, identified classes of stakeholders. Design Science Research should produce knowledge of a new solution to (i.e. how to) solve a class of problems when or where they occur, rather than a solution to a single, situated problem.

The next question that we could ask would be what kind of knowledge should Design Science Research produce? One answer is the deliverables identified above – constructs, models, methods, instantiations, and better theories. Another answer is twofold: First, it should produce guidelines and advice for practitioners that are clear and complete enough to guide practitioners' actions in choosing among different, competing solutions/technologies and in implementing their choice. Second it should produce clear, precise, and complete statements of the knowledge created so that it can be tested and enhanced by other researchers.

4. Why Should Theory and Theorising be Part of Design Science Research?

But, at what level should the knowledge be pitched? Vaishnavi and Kuechler (2004) note different levels of knowledge, as described above, with higher levels of knowledge being more abstracted or generalised, first as emergent theories and then, presumably, as received theories, accepted by the research and practitioner communities. In this paper, we assert that higher quality research fully develops generalised knowledge in the form of theories.

We agree completely with Gregor (forthcoming), when she notes,

> "Developing theory is what we are meant to do as academic researchers and it sets us apart from practitioners and consultants. In addition, there is the view that 'nothing is so practical as a good theory' (Lewin, 1945). Theories are practical because they allow knowledge to be accumulated in a systematic manner and this accumulated knowledge enlightens professional practice." (Gregor, forthcoming)

Among the papers reviewed above, March and Smith (1995) make the clearest argument that Design Science does not need to generate or test theories. They assert that knowledge can be in the form of constructs, models, methods, and instantiations.

But where is the guidance for practitioners in those? How do practitioners know which aspects of which problem situations are addressed by which (new or old) technologies, so that they can judge relevance and find which technology or technologies are appropriate? Where are the comparisons in effectiveness, efficiency, and cost between different technological solutions to the problems that they face? Put another way, how do they navigate the body of knowledge of all the different technological solutions available to them to arrive at one that is appropriate?

Similarly, how can other researchers evaluate such knowledge? How do they know in which problem situations to test the various technological solutions developed in Design Science? How can our community build up this body of knowledge over a body of time if theories are not proposed for us and our fellow researchers to refute and improve?

Further, as March and Smith (1995) note, there is "prestige attached to science in modern societies and the belief that the term 'science' should be reserved for research that produces theoretical knowledge." (p. 252). Why should Design Science fight this commonsense belief? Why should we not embrace the development and testing of theory as a part of Design Science? Rather than casting out theory and leaving it as the province of other research disciplines, we argue that we should embrace the need for theory and develop a way to make theory work for Design Science. Or, as Gregor (forthcoming) argues, "We need a language of our own to talk about theory and should not adopt uncritically ideas about what constitutes theory from any one other disciplinary area.

This then gives rise to the question of what form theories should take in Design Science. We take that up in the next section.

5. Design Theory = Utility theories

Whether theory and theorising are considered to be part of Design Science or not (we think they should be), the form and structure of theory as relevant to Design Science is an important issue. Here we consider the following questions: What qualities should each Design Science theory have? How should they be structured? The requirements for answering these questions are implied in the questions asked in the previous section – utility of the knowledge to practitioners and clarity, precision, and comprehensiveness to researchers.

Our approach builds on that of Walls et al (1992) and Markus et al (2002), as discussed earlier in this paper. However, there are a few key differences between the approach in this paper and theirs.

First, it seems unnecessary that a design theory should incorporate kernel theories, whether relevant to the "meta-requirements"/"particular class of user requirements" (respectively Walls et al, 1992 and Markus et al, 2002) or relevant to the "design method"/ "effective development practices" (respectively Walls et al 1992 and Markus et al, 2002). Explanations of how and why solutions work, while important, aren't the core issue. The fact (proven theory) that they do work and how well is the issue. Indeed, we may well know that a solution works, but not know why or how (e.g. as when penicillin was first discovered). This does not mean that we should not *use* kernel theories when forming new design theories (or hypothesising them), just that they aren't a necessary part of design theories.

Second, it also seems unnecessary that a "design method" (Walls et al 1992) or "effective development practices" (Markus et al, 2002) need to be part of a design theory, except (as noted in section two) when the design method *is* the "meta-design" (Walls et al, 1992) or "type of effective solution" (Markus et al, 2002). Walls et al

(1992) assert that both "meta-design" and "design method" need to be parts of a design theory because the word 'design' is both a noun (product) and a verb (process). However, the conclusion isn't mandated by the premise. A design method should itself be considered to be an IT artifact that can be designed and constructed. The design for a design method is itself a "meta-design" in that it will always be instantiated differently in each instance of its application. Further, one could say that the "meta-requirements" (or goals) for a design method as a "meta-design" are to enable the effective design of other design artifacts. Furthermore, there may be many different ways (design methods) to design one kind of system (or other solution technology). Design methods have their own identifiable goals and constitute an identifiable "meta-design" for a means to a particular kind of end (the design of an instance of another meta-design). Thus, the process is itself a product in some sense and only the meta-design and meta-requirements are needed in design theories, although separate design theories (for the product meta-design and process meta-design) are needed.

Third, testable design hypotheses do not seem to actually be part of part of a design theory. Hypotheses are a form of restatement of a theory in a precise, testable (falsifiable) way. However, there can be many different ways to restate a theory for evaluation or testing. As such, they seem to be an addendum, rather than part of a theory.

Fourth and finally, the idea that a design theory should be prescriptive (Walls et al, 1992) does not seem appropriate. Similarly, the prescriptive nature of a Type V Theory for Design and Action (Gregor, forthcoming) does not seem appropriate. A particular design theory would only appropriately prescribe that a particular meta-design should be applied to achieve a particular set of meta-requirements if that meta-design is *the best* in comparison to all other possible meta-designs that have utility in addressing those same meta-requirements. The ability to weigh all possible alternative meta-designs would be quite difficult, if not impossible. Furthermore, such a prescription would be complicated in that what can be said to be the "best" meta-design (that with the best utility) will change over time as new meta-designs (or solution technologies) are invented or as further evaluation research identifies weaknesses or strengths that increase or decrease our understanding of different meta-design's utility in addressing relevant meta-requirements.

Rather, it is the view here that a design theory should be a *predictive* theory about the utility (effectiveness, efficiency, etc.) of applying the technological solution or "meta-design" to solve a problem or address some "meta-requirements". Research papers could then weigh up the different utilities of known meta-designs and make recommendations about the state of the art, but that does not constitute a theory in the author's perspective. Such theories would then fit either Type III (Prediction) or Type IV (Explanation and Prediction) in the Gregor classification (Gregor, forthcoming).

What we need then is a form of design theory that focuses on the "meta-requirements" and the utility of a "meta-design" in meeting those meta-requirements. This paper proposes that an appropriate form of a design theory would be what we call a utility theory. A utility theory makes an assertion that a particular type or class of technology (i.e. a meta-design), whether it is of an IS or other system, software, a modelling language, a development or planning method or other procedure, an algorithm, or any other form of technological solution) has (some level of) utility (or usefulness) in solving or improving a problematic situation (with specified characteristics). The utility of the technological solution should be stated in term of its efficacy, effectiveness, and/or efficiency, and perhaps even its elegance (aesthetics) or ethicality (the 5 E's, cf. Checkland and Scholes, 1999) in addressing the problem. The level of utility should also be stated in a way that is comparable to the utility of other technological solutions for similar types of problems, preferably with some form of metric or measure.

Below are some prototypical (if simplified) examples or forms of utility theories.

- (New) Technology X (when applied properly) will help effectively solve problems of type Y
- (New) Technology X (when applied properly) will efficiently provide improvements of type Y
- (New) Technology X (when applied properly to problems of type Y) is more effective than technology Z

"Technology X" can be thought of as a meta-design (Walls et al, 1992), comprising any one or a combination of the various technologies mentioned in the above paragraph. As a result of Design Research, "technology X" would typically be new. Alternatively, it could be established, but applied to a new problem. In a properly constructed utility theory, "technology X" needs to be clearly and completely identified and clearly related to and differentiated from other existing solution technologies.

Proper constructions of utility theories should also include precise definitions of the (type of) problem to be solved ("problems of type Y"). In the language of the prototypical forms above, 'problems of type Y' must be carefully identified and should be well understood. This implies that problems must be well diagnosed.

The nature of the utility (or utilities) in improving or solving the problem should also be clearly stated in a well-formulated utility theory. Figure 2 gives a visual representation of how these elements may be combined into utility theories.

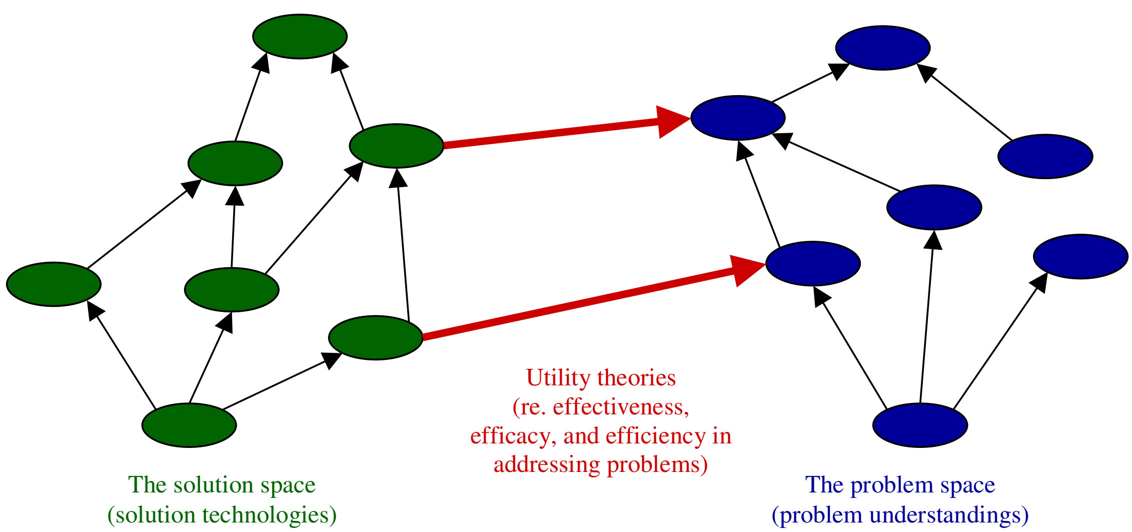

Figure 2: Components of Utility Theories

In figure 2, the problem space represents the researcher's understanding of the problem(s) being addressed by a proposed technological solution, specified and placed in context by relationships with other problems and problem aspects. The relationships between concepts in the problem space may be aggregation, generalisation, or other kinds, but especially causal links. The problem space is similar to, but extends, the notion of 'business needs' in Hevner et al (2004). It is also consistent with the idea of "meta-requirements" in Walls et al (1992). Ideally this description of the problem space would draw on descriptions developed in prior Design Science Research, which would help lead toward comparability of the results of different Design Science Research efforts. Descriptions of the problem space could then be used by practitioners to identify technologies relevant or applicable to their situated problems.

The solution space in figure 2 provides a description of the concepts that describe the type of solution, including relevant relationships between the concepts. It is similar to the "constructs" and "models" of March and Smith (1995). It is also consistent with the idea of a "meta-design" in Walls et al (1992). If the technology is a development or other method, a process or an algorithm, then it may be similar to a "method" as in March and Smith (1995) or a "design method" in Walls et al (1992). The relationships between the concepts in the solution space (arrows in figure 2) may be aggregation or generalisation or possibly of other kinds. Note that the solution space part of a utility theory by itself would correspond to Gregor's Type I (Analysis) theory in that it includes no causal relationships (Gregor, forthcoming).

A utility theory then links some concept or group of technology concepts to the aspects of the problem(s) that it/they address. The meaning of the utility theory should be specified in terms of the impact on the problem space, hence the direction of the arrow in figure 2.

Note that developing a thorough understanding of a problem space (problem diagnosis) may be a distinct form of research as well, but as a precursor to Design Science Research. A 'problem of type Y' may fit within the problem space in figure 2 in the form of a classification of types of problems and/or may be some combination of other types of problems. What is essential is that the utility theory clearly identifies the problem(s) that the (proposed) technological solution addresses. Of course, better problem diagnoses may be a result of Design Science Research as well.

A Medical Analogy

At this point, it may be useful to develop an analogy from medicine. The problem space is like diseases. Diseases have causes and are related to other diseases. The solution space is like treatments. A particular treatment may be a kind of another treatment or may be a composite of several other kinds of treatments. In medicine, the study of disease pathology (how diseases work and affect humans) is an essential sub-discipline, which informs the design of treatments. Disease pathology research is essentially research into the problem space.

Having an understanding of a disease pathology (or of 'business needs' in the language of Hevner et al, 2004) means that we understand the disease (or problem space), how it works, what the causes of the disease (or problem(s)) are, what the implications or consequences of the disease (or problem) are, what other disease factors (or other problems) contribute to or are caused by the disease at hand and so forth. These understandings all influence the design of treatments (or more generally, solution technologies), which have the goal of elimination, reduction, or alleviation of a (potentially) undesirable circumstance (and therefore making an improvement).

Like new medical treatments, new technological solutions are designed to work in two main ways.

- Compensating for undesirable circumstances (treating the symptoms)
- Eliminating or reducing one or more of the causes (treating the disease)

Any utility theory proposed should be precise about what problem(s) the technology addresses, what way it addresses the problem(s) (as above) and what benefit would occur from applying the technological solution.

Perception and Different Views of Problems

The nature of problems requires that each Design Science researcher clearly asserts the problem(s) that he or she is attempting to solve through the research. David Kroenke (citation unknown) gives a concise, but pithy definition of a problem as:

> "A perceived difference between what is and what should be" (Kroenke)

A key aspect of this definition is that problems are perceived (not part of an objective reality), which implies that problems are perceived differently. Each problem viewer (stakeholder) has a different weltanschauung (Checkland and Scholes, 1999), world view, or understanding of the undesirable implications and causes of 'the' problem. Each problem viewer also has different personal values that characterise the difference between what is and what should be as undesirable. The "what should be" in the definition concerns a desirable state for the problem perceiver(s), not necessarily some "ultimate good". As researchers, it is important that we not miscommunicate about our understandings of the problem space. It is important to note that a shared or obvious understanding often does not exist among Design Science researchers or among practitioners. Therefore, clear and complete statements about the problem space being addressed are needed in design/utility theories.

Clear and complete statements are also needed on the technology (solution space) side of a utility theory. Each new technology (e.g. a medical treatment) is based on and related to other technologies that have already been invented. For example, a new medical treatment may combine other treatments, make a small enhancement to an existing treatment, or even be a revolutionary new approach. Whichever of these, new technological solutions (or treatments) are always related to and contrasted with existing approaches.

6. The Theorising or Theory Building Activity

Theorising and theory building occur before, during, throughout, and at the end and as a result of Design Science Research.

Theorising in Design Science Research begins with the spark of an idea, a nascent concept for a not-yet-existing (or not-yet-applied) technology as the solution for a problem or type of problem. This spark of an idea may come from

- Recombining ideas and conceptualisations of problem spaces
- Realising new possibilities for solutions
- Recombining existing solutions/technologies
- Imagining new technologies
- Realising new applications for existing technologies

As noted in Hevner et al (2004), Design Science Research is informed both by existing theory (better if it includes high quality utility theories) and by business needs.

As a precursor to Design Science Research, it is desirable to formulate a utility theory or hypothesis of a kind of approach to reduce the problem. This process of utility hypothesis formulation correlates to the use of abductive reasoning as shown in Vaishnavi & Kuechler (2004, see their Figure 3: Reasoning in the Design Cycle), which cites Takeda et al. (1990). While theory or hypothesis formulation is often implicit, it is better in Design Science Research if this is done explicitly and explored fully. This leads both to clarity and reduction of the chance of duplicating results.

At this initial stage, a new technological solution may not yet exist. During the building stage, the nascent idea for a new solution is fleshed out with detail. Software is designed and built; features are added (and deleted); new modelling concepts or representations are designed. All of this is carried out being mindful of the goals (problem solution) and other existing design artifacts. New insights may be gained into the problem space and how to address it with technology. Therefore, during the building stage of the technology, new concepts and constructs will be created and need to be added and integrated into the description of the solution space. It is also likely that the problem space will be re-conceptualised and that new links between the spaces (new utility theories for part or all of the technology being designed) will be hypothesised along the way. This is similar to Vaishnavi and Kuechler's (2004) idea of emergent theory as discussed further above.

During the build process, the utility theories developed are as yet untried and unproven (indeed they will never be proven). Of course any one technology may make use of or be similar to other technologies and benefit from existing (and tried) utility theories relating to them.

In addition to theory building before conducting Design Science Research, theory building should also be accomplished following technology invention and evaluation (at the end of Design Science Research). When technologies are evaluated, the utility theories are examined for truthfulness. This is an important part of any scientific approach.

Evaluation results in understandings of a solution technology's effectiveness, efficiency, etc. for solving or alleviating the problem(s). A solution technology is also commonly evaluated in terms of its cost, organisational practicality, and other criteria, relative to other potential means (solution technologies) to solve or alleviate the same problems. These findings all need to be incorporated into theory.

7. A Framework for Theorising in Design and Other IS Research

In this paper, we have asserted that theory and theorising should play a key role in Design Science Research. Indeed, theory can be viewed as the link between researchers and different research activities over time. Theories are proposed by someone and analysed, validated, refuted, modified, enhanced, evolved, and, hopefully, accepted and adopted over time by many. Indeed, they may be modified many times during a single Design Science Research project. Thus, theorising or theory building is a central activity, which ties together various areas of research.

Figure 3 shows how theory building is a central activity related to problem diagnosis, technology invention or design (to solve problems), and technology evaluation. While problem diagnosis and technology evaluation may be undertaken in the empirical domains of natural and particularly social/behavioural sciences, theory building is the necessary link between them all.

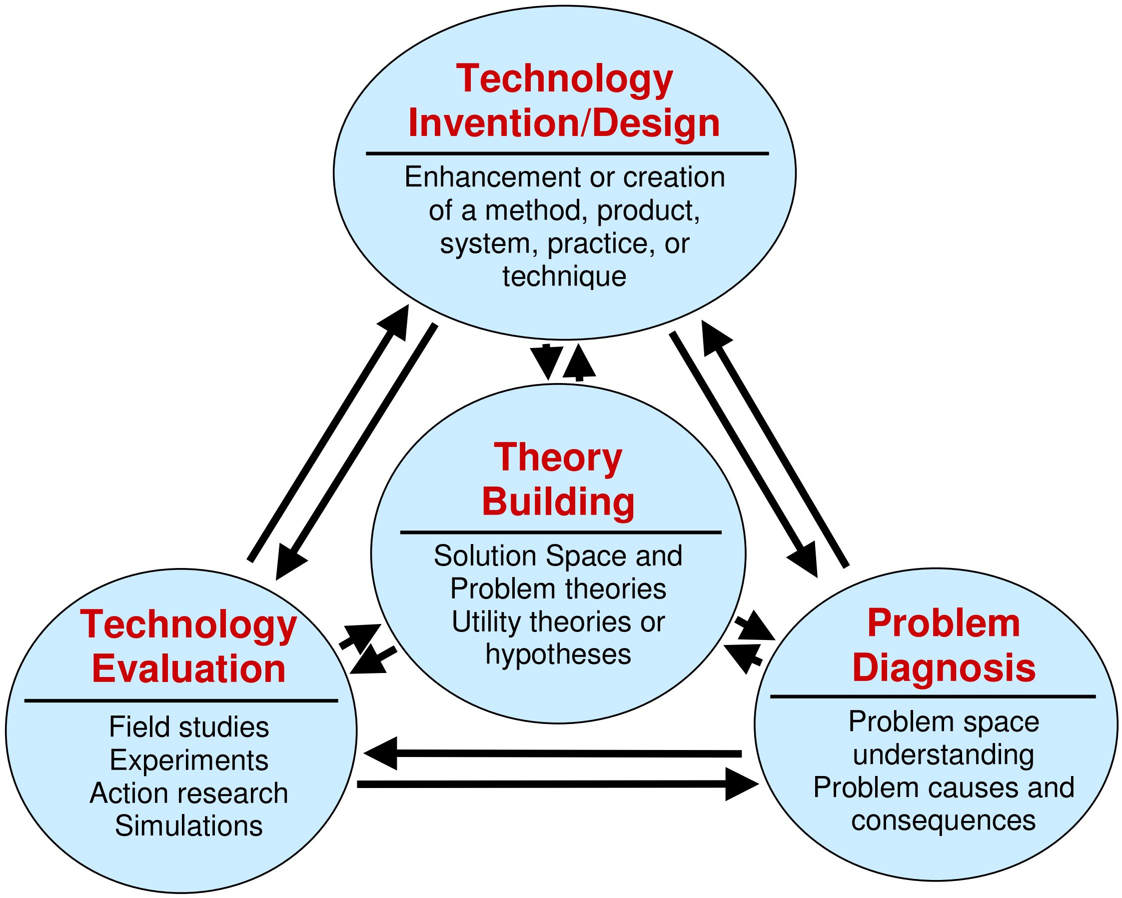

Figure 3: An Activity Framework for Design Science Research

8. Summary

This paper has taken the position that Design Science Research must not leave theory and theorising to the natural and social (empirical) sciences. Instead, Design Science researchers should engage in theorising – before, during, and as a result of Design Science Research work. The paper proposed that design theory should be in the form of utility theories, which relate improvements expected from applying a particular type or types of technologies ("meta-designs" in Walls et al, 1992) to a particular type of problem ("meta-requirements" in Walls et al, 1992 or "user requirements" in the terms of Markus et al, 2002). It is also considered essential that sufficient detail and clarity be attached to all three parts of a utility theory – the problem space, the solution space, and the nature of the utility that links them. These details are necessary because of the differences in viewpoints that prohibit them from being left implicit. The details also ensure that we are communicating theory in a way that it can be understood by practitioners and by the Design Science researchers who will work to improve the theory. Theory and theorising/theory building are then seen as a central research activity, in common with all research approaches.

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