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THE RANGE AND ROLE OF THEORY IN INFORMATION SYSTEMS DESIGN RESEARCH: FROM CONCEPTS TO CONSTRUCTION

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Completed Research Paper

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Abstract

This paper reports results from a field study of cross-disciplinary design researchers in information systems, software engineering, human-computer interaction, and computer-supported cooperative work. The purpose of the study was to explore how these different disciplines conceptualize and conduct design-as-research. The focus in this paper is on how theories are used in a design research project to motivate and inform the particulars of designed artifacts and design methods. Our objective was to better understand how elements of a theory are translated into design action, and how theoretical propositions are translated and then realized in designed artifacts. The results reveal a broad diversity in the processes through which theories are translated into working artifacts. The paper contributes to our understanding of design research in information systems by providing empirical support for existing constructs and frameworks, identifying some new approaches to translating theoretical concepts into research designs, and suggesting ways in which action and artifact-oriented research can more effectively contribute to a cumulative and progressive science of design.

Keywords: Action research, design method, design practice, design science, qualitative research.

Introduction

This paper reports results from a field study of cross-disciplinary design researchers in information systems, software engineering, human-computer interaction, and computer-supported cooperative work. The purpose of the study was to explore how these different disciplines conceptualize and conduct design-as-research, a form of action research where technologies are designed and created to influence positive change. The focus in this paper is on how theories are used in design research to motivate and inform the particulars of designed artifacts and design methods. Among the objectives of the work was to better understand how elements of a theory are translated into design actions, and how theoretical propositions are realized in designed artifacts. Results from the study reveal a broad and inclusive diversity of thinking about what counts as a theory, and on how theoretical propositions are used to guide design research. The paper contributes to our understanding of design research in information systems by providing empirical support for some existing constructs and frameworks in design science, identifying some new approaches to translating theoretical concepts into research designs, and suggesting ways in which action and artifact-oriented research can more effectively contribute to a cumulative and progressive science of design.

A defining characteristic of design-as-research is that artifacts created during this kind of study are explicitly inscribed with theoretical constructs. Such theory-led design may be guided by laws, principles, analytic generalizations, empirical generalizations, unobservable theoretical entities, and other propositions obtained from one or more theoretical frameworks. Information systems as a discipline has an increasingly rich body of knowledge concerned with theory use in design research, including among many others (Gregor 2006; Gregor et al. 2007; Hevner et al. 2004; Walls et al. 1992) Much of this work is, however, analytic rather than empirical. Results reported here were derived from a set of 68 cross-disciplinary interviews with design researchers from information systems, software engineering, human-computer interaction, and computer-supported cooperative work. The naturalistic, empirical views revealed by the study lend support to existing knowledge and point to some new ways that theory is used or can be used in design-as-research.

Taken together the knowledge embedded in a theory provides a framework for understanding, explaining, and/or predicting events in its domain of interest (Gregor 2006), as shown in Figure 1 below. In essence, theories provide the conceptual 'glue' to integrate otherwise disconnected knowledge into explanations and predictions of a particular domain. According to Hempel's "symmetry thesis", explanations and predictions differ only by their position along the time dimension (Hempel et al. 1988). In other words, the knowledge that counts as an adequate explanation of an event that *has* occurred can also be used to predict an event that *will* occur. The theoretical propositions that bind together the formal, empirical, and analytic components of a theory represent the **knowledge gaps** within a theory. In information systems design research, these knowledge gaps are often functional gaps, areas of missing capability within a domain where it might be supposed that technology can be fruitfully applied to support and enhance some human activity.

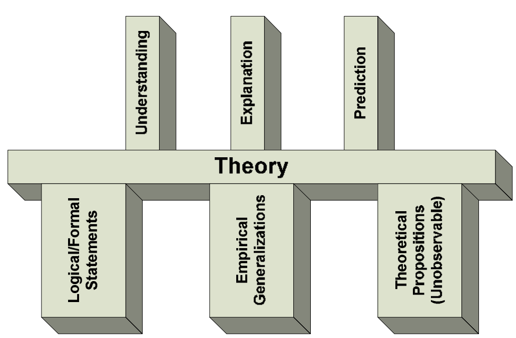

Figure 1 Theory Foundations and Uses

Wide acceptance of any single definition for what constitutes a theory has proven elusive, and it is not our intention here to promote any one of the many definitions that exist. One conventional view from the philosophy of science is that a theory is an assembly of domain or aspect-specific knowledge typically consisting of logical formal statements (which may or not be mathematical), empirical generalizations, and theoretical propositions about unobservable entities or forces (Carnap 1966). Based on this relatively straightforward definition (only one of many in the philosophy of science), theories might be viewed as contributing to design by providing a particular understanding of the problem domain; by explaining why people act in a particular way when engaged in an activity in the domain; and/or by predicting what forms of technology might be most effective in support of this activity. Many have argued that it is just this theory-ladeness that qualifies *some* design and construction as a form of research, rather more instrumental (e.g. commercial) development.

Researchers in information systems and other disciplines engaged in creation of information technology often claim that artifacts produced as the object of a research program embody or otherwise inscribe and represent a particular theoretical perspective (Gregor 2006; Haynes et al. 2008; Walls et al. 1992). In this paper, we make at attempt at unpacking these claims to better understand how theories are **translated** into working artifacts, and then reflected upon once they have been inscribed into working systems. An underlying premise is that through such understanding, design researchers may be better equipped to select appropriate theories for design, effectively and *explicitly* translate these theories and their underlying content into valid theoretical constructs, and then evaluate whether a particular theory so translated has proven effective in helping to guide creation of useful and usable information systems.

Of particular interest here is the use of reference theories, or what have been called *kernel theories* in the literature on information systems design theories (Walls et al. 1992; Walls et al. 2004). These are theories typically drawn from outside the set of specific methodological or structural theories which prescribe particular designs. Very often they are social or behavioral theories that say something about human interaction with artifacts either in use and/or in context, or they provide guidelines for the process of design and construction. This paper contributes to the literature of design research in information systems by providing empirical grounding for some existing ideas, and by identifying some less commonly recognized ways that theories are used to formulate and conduct design and research artifact construction. It also contributes by exploring some of the specific *means* through which researchers translate theories into understanding, decisions, and actions in the design process. This latter contribution is, we believe, unique in the literature and important to extending our understanding of the design research process. Finally, the paper contributes to understanding at the intersection of design science and action research by showing how research undertaken to enact change can both integrate and embody state-of-the-art design knowledge, and "talk back" to the state-of-the-art with important new insights.

The paper first provides a brief review of research most closely related to that presented here. We then describe an interview-based study designed to explore some of the motivations and means underlying modern day design research in information systems, human-computer interaction, computer-supported cooperative work, and software engineering. Data collected from these interviews are then analyzed and presented with a particular focus on the use of theory in design research including what, how, and why theories are used. The Discussion section gives some implications for design research in information systems and related disciplines before the paper concludes.

Background

Researchers have long recognized that technology artifacts are under-theorized in the information systems literature. Orlikowski and Iacono (Orlikowski et al. 2001), for example, have shown that the bulk of IS research as represented by publications in the journal *Information Systems Research* focus far more often on the context in which technologies are used, and on the behavioral theories that explain people's response to technologies *in situ*. Notably absent is an explication of the relationship between the behavioral/contextual perspectives and their computational implementations including specifications of how theoretical positions in the behavioral sciences are translated into designs.

Orlikowski and Iacono conclude with a call for IS researchers to be more explicit in their theoretical and conceptual treatment of the technologies that are among the central concerns of the discipline. In particular, they call for increased attention to the way in which both designers and designs are influenced by the values, interests, and assumptions of prospective users and other stakeholders. In design research, one possible target for this attention are the theoretical lenses which designers employ in their shaping of design representations and material artifacts. As they point out, both the properties of the materials at hand, for example, programming languages and other development platforms, and the context in which these materials are used are *causal mechanisms* that implicitly shape the form that a particular technology takes. This process of how concrete artifacts emerge is little understood, however, and design researchers need better ways to examine, capture, and communicate how and why a particular technology supports human activity in new and better ways.

Acknowledging how little is known about the use of theory as an input to design, March and Smith (1995) focus on the use of theory for *post hoc* rationalization and justification for why a particular design functions effectively in a particular context. Their conceptualization of the use of theory in the design process is minimized in favor of their use in the interpretation of the constructs, models, methods, and instantiations that result from implementation. Though they do not highlight this explicitly, clearly in any iterative design program these results and their incorporation into new or existing theories lay the ground work for subsequent design efforts. This period of *reflection-on-action* (Schön 1983; Schön 1987) between design-build-evaluate iterations presents one potentially fruitful opportunity to theorize about a particular instantiation of a design theory and its performance in context.

In recent years, researchers in information systems have increasingly focused on the development of information systems design theories (ISDTs) as one of the primary means to structure design-build studies as true research endeavors. Walls et al (1992) describe ISDTs as made up of seven components divided into *design product theory* and *design process theory*. Design product theory components include: meta-requirements, meta-designs, **kernel theories**, and testable design product hypothesis. *Design process* theory components include: design methods, kernel theories, and testable design process hypothesis. The ISDT framework has proven useful in helping to guide information systems design researchers in formulating, conducting, interpreting, and communicating results from research projects with a substantial design-build emphasis.

Especially relevant to the work reported here are kernel theories, which are reference theories from the natural and artificial sciences. According to the originators of the ISDT approach, these theories "prescribe design products and processes for different classes of information systems as they emerge" (Walls et al. 2004) and help in developing boundaries for design assumptions. One formulation is that these theories support making the problem domain tractable for designers by "focusing their attention and restricting their options, thereby improving the development outcomes". ISDTs are normative in nature, have explanatory and predictive powers and support design practitioners in their work by restricting the range of possible system features and development activities to a manageable set (Markus et al, 2002). This represents one of the few articulations of exactly how theories are translated into design actions. An open question is whether this bounding function is the only mechanism through which explicit use of theory can help guide the design process. Surely theories can also suggest ways to explore or even extend these boundaries?

Other research has focused on developing criteria for evaluating design theories. For example, drawing from Simon (1969), March and Smith (1995) develop a distinction between the natural and design sciences arguing that design sciences involves building and evaluating *constructs* to characterize specific phenomena; *models* to help in describing specific tasks and artifacts; *methods* to guide the assembly of activities for achieving design goals; and *instantiations,* which are implementations designed to support target tasks and activities. As discussed earlier, however, their approach to the use of theory in design is focused on retrospective analysis of a particular theory's efficacy, rather than on the means through which theories are translated into design reasoning, design *action*, and ultimately into working systems.

Hevner et al (2004) also propose criteria for evaluating design theories and, similarly, they are largely focused on the newness of the design, matching the artifact to requirements, and generating results from evaluation that provide evidence for the efficacy of the design. Two of the criteria, however, do center on process issues that are intended to differentiate design research from design-as-practiced. The first of these is very general and is identified as *research rigor*, which prescribes the use of rigorous research methods in the construction of the artifact. The second proposes more specific sub-criteria that specify both a comprehensive search for appropriate artifact forms relative to the alternatives available, and consideration how the constraints that exist in the problem domain are accounted for in the artifact's implemented form. The latter criterion especially points to some of the concrete ways that a particular design effort can account for existing knowledge, both theoretical and practice-based.

Gregor and Jones (2007) go further in describing how the inputs to a research design process and subsequent reasoning about how they impact artifact form and function can be structured to account for both existing theories and new theoretical objectives. They propose eight components of an ISDT including (a) purpose and scope, describing the meta-requirements or goals that specifies the type of artifact for which the theory applies (b) constructs which define the "representations of entities of interest" (c) principle of form and function, which is the architectural description of the artifact or the method (d) artifact mutability, describing the degree of changes of the artifact that are explained by the theory (e) testable propositions, which include predictions that can be tested (f) justificatory knowledge is the knowledge that is derived from natural or artificial sciences (g) principles of implementation describe the processes of implementing the theory and (h) expository instantiation, which shows examples of the design theory in action. What differentiates this account of design-as-research is its focus on how knowledge, including theoretical knowledge, can be harnessed before and during the specification and instantiation of a design.

It is their specification of ISDT kernel theories as comprising the "justificatory knowledge" underlying the form of design which speaks most directly to how these theories act to guide the design process. In this conception, the kernel theories in an ISDT act as part of the rationale underlying design decisions. In particular, they act as the *warrants* (Toulmin 2003) supporting a particular position on a design decision, for example, supporting the weighting of one design criterion over another relative to the intended purpose and context of the design in question. The strength of this approach is that it makes explicit how existing knowledge is used to guide and constrain design moves. Assuming this design rationale is captured and documented, which is optimistic, designs and artifacts created in this way are linked to the thread of reasoning that led to their realization.

At a higher level of abstraction is work by Gregor (2006), which describes a taxonomy that organizes IS theories into five distinct types including theories for analysis, explanation, prediction, explanation *and* prediction, and for design and action. Of particular interest here is the conception of theories for *design and action*, we will suggest later that *all five* types of theory may in fact play instrumental roles in design research. According to Gregor, theories for design and action tell us "how to do something" and give "explicit prescriptions (e.g., methods, techniques, principles of form and function) for constructing an artifact." The emphasis is on action, especially principled and knowledge-driven action, in design and construction of working information systems.

Gregor characterizes theories for design and action as consisting of a specific set of components resonant of the information systems design theory concept discussed earlier. The components include: a means of representing the design (e.g. diagrams; ontological components such as constructs and their relationships; the scope of the theory, including its domain and purpose; causal explanations that draw on underlying kernel theories; testable propositions; and prescriptive statements about how user requirements might be met with a particular design.

Gregor and Jones' idea that **principles of implementation** as describing the processes of theory implementation also addresses the problem of theory translation and its specific mechanisms. Gregor (2006) explores this idea further in her description of theories in information systems, specifically, her Type V theories, theories for design and action, which are developed specifically to guide the construction of new artifacts in a research context. One issue with the ISDT conception relates to the level and granularity of their design prescriptions. Whether a class of designed artifacts meets or does not meet a class of meta-requirements is perhaps both less useful and more difficult to show than whether more specific design parameters and criteria are relevant to specific design problems that emerge from the unique attributes of a given problem domain. For example, in the original ISDT paper (Walls et al. 1992), the class of information systems being studied was executive information systems (EIS), but the specific design feature of concern was the vigilance construct. This more granular design criterion, vigilance, is not a class of information system but a criteria that can be parameterized with respect to a range of domains, not only EIS.

Technology has been characterized as "society made durable" (Latour 1991), that is, Designers and engineers are said to inscribe their accumulated knowledge into the form and function of the tools they create (Hutchins 1995; Latour 1987). Many of the problems addressed in the information technology development lifecycle, especially in complex, interactive systems, are inherently ill structured, even 'wicked' (Rittel et al. 1973). Problems arise and are (hopefully) resolved during requirements analysis and specification, design deliberations and decision, and the iterative cycles of construct and test, which are all knowledge intensive activities. In the realm of the commercial designer and developer, this knowledge is often the product of experience, perhaps coupled with fragments of the reified knowledge they acquired in their higher education or professional training courses. Absent any structured principles or standards, the mechanics of how this knowledge is used is often described as a craft-like or even artistic process. So too in design research, where exactly how scientific theories and other structured knowledge are translated into working artifacts is still very much a mystery.

In the following sections we describe a field study undertaken to elicit and analyze the perspectives of design researchers from different fields in the broad realm of information technology. This study was undertaken with the explicit aim of furthering our understanding of the ideas discussed in this Background section. Specifically, these results are best seen as providing **empirical support and empirical extensions** to the idea that theories can and should be used to motivate and guide design and construction of research-oriented artifacts.

Method & Procedures

The general method employed was qualitative and involved interviewing study participants in a naturalistic setting. The study procedures involved interviewing design researchers in information systems, software engineering, human-computer interaction, and computer-supported cooperative work. Design of the interview guide was focused on revealing their underlying perceptions of design research and how design fits within their research program, the ways in which theories are used as part of their research program, and the different kinds of knowledge that result from design research. The interview guide is intended to elicit fundamental perceptions about the nature of design, design as a research endeavor, theory use in design research, and the role of design research as a contributor to scientific knowledge.

Interview participants were selected from the author and attendee lists of the following conferences: the 2007 International Conference on Design Science Research (DESRIST); the 2007 Americas Conference on Information Systems (AMCIS); the 2006 ACM Computer-Supported Cooperative Work (CSCW); 2007 ACM Human Factors in Computing Systems (CHI); and the 2007 International Conference on Software Engineering (ICSE). Our intention was to gain a broad, cross-disciplinary understanding of how design is employed in these different fields of inquiry. Most study participants were academics, though a small number work as design researchers in commercial settings.

A total of 68 researchers were interviewed. Our goal was to have an equal number of interviewees from each of the four represented fields. Arguably we achieved this though several researchers currently cross disciplines or have migrated from one field to another. In some cases contact was first made at the conference with the actual interview taking place by telephone in the weeks following.

Interview participants were prominent researchers in their respective fields. Most had over 10 years of experience conducting design research and many reported they had been in the field for over 20 years. In general we found that study participants engaged enthusiastically with the topics in the interviews.

Three graduate students conducted the interviews, which lasted from 20 to 90 minutes. During the interview, we used an interview guide (a questionnaire) along with a set of probes for each question to uncover details about how researchers see their design research contributing to explanation and understanding. The interview guide appears in the list below.

1. What are your major research areas?
2. In what discipline were you trained?
3. In what discipline do you work now?
4. How long have you worked in design?
5. What role does *design* play in your work?
6. How have you used theory in your design work?
7. What are the main goals of your research with respect to design?
8. With respect to those goals, do you seek to describe, explain, control, or predict some phenomenon through design?
9. What is an example of how your design work provides a scientific understanding of a specific phenomenon in your field of interest?
10. What is an example of how you used a scientific understanding produced by prior work?
11. How would you characterize an ideal scientific understanding?
12. What could be done to improve the utility of scientific understandings produced through your design work?
13. Are you familiar with theories of explanation from the philosophy of science?

Interviews were recorded and transcribed for analysis. We used Atlas/ti (www.atlasti.com) to support the coding process. The approach we took to coding was based on methods drawn from grounded theory (Glaser et al. 1967) and employed qualitative data diagramming and visualization techniques suggested in (Miles et al. 1994). These visualizations were used in concert with data displays provided by Atlas/ti to better understand where codes were seemingly distinct, where codes overlapped significantly, and how different codes and the concepts they represent are linked through their underlying attributes.

We first coded the data using the *open coding* technique. Code categories were then factored and re-factored through group iterative analysis and interpretation of the data (axial coding). Finally, those code categories with the greatest theoretical density were selected (selective coding) for inclusion here. As is apparent in the following results section, we have combined our own analysis and interpretation of the data with a substantial number of quotations drawn directly from the interviews.

Results

This section provides results from the field study showing the diversity of theories used in design research and suggesting seven ways that theories are used in the translation of concepts into concrete instantiations of those concepts as working systems. Our objective here is to present the data largely as-found, with direct quotations as examples of the conceptual categories.

Important to note in this section is that although the study drew on participants across disciplines, the results are presented here in a holistic way, that is, we made little if any effort to analyze the data from a comparative perspective, though we do intend to conduct such an analysis in future work.

The diversity of theory in design research

The analysis shows the breadth of theories, even the breadth of ideas about what constitutes a theory, that were evident in researchers' experience with theory use in design research. Also broad was the range of different ways that researchers appear to make use of theories in their design-as-research activity. Table 1 below shows the scope of the theories informing design research across disciplines. Note that the list of named theories is derived from participant answers regarding the theories they use. No attempt was made to decide whether a particular answer actually referred to what is generally regarded as a theory. Also, in some cases it was clear that participants were alluding to a specific theory, but when it was not explicitly named it was excluded from this table. It should be assumed that the list of theories participants use in their design research projects is more extensive than the one provided here.

Table 1 Theories Identified as Informing Design Research

Activity Theory	*Actor-Network Theory*	*Adaptive Decision Making*
Algebra Theory	*Automata Theory*	*Chicago School Sociology*
Complexity Theory	*Constructivist Design Theory*	*Contextual Inquiry*
Cooperative Inquiry	*Coordination Theory*	*Critical Social Heuristics*
Critical Social Theory	*Design Patterns*	*Distributed Cognition*
Domain Theory	*Ethnomethodology*	*Fitt's Law*
Grounded Theory	*Information Systems Design Theory*	*Instructional Design Theory*
Logic Theory	*Modularity Theory*	*Option Value Theory*
Participatory Design	*Personal Construct Theory*	*Phenomenology*
Reflective Design Theory	*Situated Cognition*	*Structuration Theory*
Economics of Information Access	*User-centered Design*	*Value Sensitive Design*

The degree of diversity was perhaps to be expected given the cross-disciplinary nature of the study, but still points to some potential issues with cross-discipline communication and knowledge sharing. Effective knowledge sharing relies on among other things a shared vocabulary to keep the cost of communication under control. In other words, researchers from different disciplines may be more efficient sharing knowledge if the overload of background learning is kept to a minimum. Quite a few conceptions of theory discussed by participants conform to commonly accepted definitions and structures in the philosophy of science (see Introduction and Background sections). For example, several participants identified Fitt's Law as a theoretical position they draw on in their design work, but most common conceptions of what constitutes a theory would say that a law may be part of a higher-level theory but, by definition, is not itself a complete theory.

The diversity evident in this list has both positive and negative implications. Among the positive aspects are that clearly, design researchers are reaching out to relevant reference disciplines to draw upon both new and emerging theoretical ideas. On the negative side this diversity presents challenges to the communication of ideas and results across disciplines, and to the progressive accumulation of knowledge within a shared framework.

As might be expected, researchers in software engineering more frequently drew on technical theories that provide specific prescriptions for design action while HCI and CSCW researchers drew heavily on reference theories from the social sciences. Somewhat surprising is the relatively small number of organizational and management theories, though they are evident, for example, in Structuration Theory, Option Value Theory, and of course in ISDTs.

Approaches to theory translation

From our data we identified seven ways that participants use theories and their elements in the translation of concepts and ideas into working information systems. These categories should not be seen as exhaustive or independent, there is obvious overlap between some or all categories and their emergence was the result of interpretive analysis of the interview data. The seven categories appear in the list below and are further elaborated in the sections that follow, Example quotations from the interviews are given as appropriate and as space allows.

1. *Theory as idea bank*
2. *Theory as methodology*
3. *Social theories identify problems and opportunities*
4. *Technical theories suggest solutions*
5. *Theories identify knowledge gaps*
6. *Theory guides reflection on design*
7. *Theory use is often implicit or tacit*

Though these categories are clearly not entirely independent, each describes what we feel is a distinctly different way that researchers approach translation of theoretical propositions and entities into design representations and working information systems.

Theory as idea bank

One prominent use of theory in design is as a kind of idea bank or knowledge base, providing both direct prescriptions for design action and more subtle raw material to fuel design reasoning. As one participant put it:

"Then there is a third type of theory which I call an orienting theory, which is how I describe the phenomenology which it needs you to ask certain kinds of questions and focus your attention on certain aspects of what you are doing without trying to give any kind of a quantitative measure or correlation or something like that."

This approach was particularly prevalent with participants describing theories as contributing to a certain *"philosophical stance*" towards design in a given domain. This approach is generally pragmatic with researchers picking and choosing elements to suit their immediate needs, seemingly without any dogmatic attachment to any single theory and its coherent strand.

"I try to steal as many ideas useful from many places [as] I can."

Using theories as idea banks may be particularly useful when approaching new domains where little or no technology development has occurred previously. Without other knowledge to anchor initial design moves, the use of reference theories from the target domain may provide an initial grounding to guide analysis and identification of key technology gaps and opportunities. Participants acknowledged that this kind of top-down understanding worked best when augmented by bottom-up gathering and analysis of data from prospective users and other stakeholders.

In fact, participants sometimes implied that this kind of "due diligence," harnessing existing knowledge to create a principled design, was a necessary condition differentiating design-for-production from design-as-research. One way this is achieved is through creation of inter-disciplinary design teams, drawing team members from disciplines in the proximity of the target domain, as a means to increase the scale and scope of the knowledge base accessible to these tasked with artifact design and construction. Another participant, taking the relatively rare position that theories have pragmatic and economic value, argued that use of existing theories was one way to reduce the time and effort needed to understand a domain and uncover its key design challenges and opportunities. Another participant put it this way:

"One way I use theory is that it helps constrain what I know."

Another related view points to the value of design rationale and the savings to be gained through re-use of prior design cognitions. In this way existing theory enables design researchers to re-use a structured packet of domain and design-specific knowledge.

"keep[s] you from having sort of recreating the rationale for why you pick up a particular solution."

An interesting point was that there are sometimes significant time lags between a researcher's exposure to a theory and its use to inform a specific approach to design:

"I first encountered phenomenology as an analytic approach during my comparative religion degree, about 1984 I guess, and then I first started thinking seriously about phenomenological approaches to design analysis in 2006. So that is 22 years later."

Still somewhat mysterious are the means by which researchers select those theoretical elements they think are most useful and productive in design reasoning. There are apparently criteria of appropriateness that have yet to be uncovered. Some remarks by participants suggested that theories provide the basis for the development of *solution patterns* that can be later used in design to match patterns to potentially appropriate solutions.

Some researchers interviewed in the study suggested that theories provide designers with a basic ontology to help understand a domain or field of interest. One of the defining traits of a theory is that it identifies concepts and the relationships between them. Such theories may be especially useful when drawn from the social and behavioral sciences and employed to explain what, how, and why people undertake certain activities to achieve certain aims.

"Specifically in terms of providing the foundation and, of different structures and to understand the relationship between the different structures."

Theory as methodology

Opposite on the scale of specificity is the use of theory as a very direct prescription on how to approach a particular class of design problem in a particular domain and with a particular set of tools to-hand. Methodologies by definition are prescriptive in that they specify a particular set of activities often in a particular order with the explicit or implicit theory that the methodology in question is a better way to approach the systems design and development problem. Just as artifacts inscribe theory, so too do methodologies embed prescriptions for how best to support human activity. All methodologies are prescriptive, though they range from the less exacting, such as the so-called agile methods movement, to those that prescribe activities to the sub-task level including how communication should occur between designers, and how these communications should be captured and reified.

Methodologies were sometimes positioned as theories of design that generalize and organize best practices into structured assemblies of activity including communications and supporting artifacts. Just as a theory helps leverage and direct knowledge towards a domain of interest, so too do methodologies act as containers for knowledge about what process has worked well in prior development efforts. They help avoid development of what one participant called *"point solutions,"* which are solutions that worked well in a particular context but which we insufficiently codified to support later reflection and adaptation in new domains. For example, as one participant framed it:

"I think that the methods we apply, the techniques that we use in doing participatory design are theory based, so for instance when we say that it is not a good idea to sit around the table and talk with users about ideas for new designs, that the only way that they can get a good understanding of what a new design will mean for them is to sort of experience it through some kind of simulation of future work where they get hands on experience. That is sort of a long theoretical argument why we believe that's true."

Another perspective that emerged was of theory and methodology existing in a reflexive relationship where the theory posits conceptual elements and the methodology reifies these concepts in prescriptions for action. Employment of a methodology thus becomes a kind of experiment with the results "talking back" to inform the validity, empirical strength, and predictive power of both the theory and the derived methodology. For example:

One participant argued that methodologies were not theories because they include no testable hypotheses. When coupled with both controlled and field studies, however, it would seem that a methodology might be viewed as a theory when empirical results are leveraged to either support or refute the efficacy of particular activities and artifacts in the design process.

Social theories identify problems and opportunities

An important component in understanding design research is understanding the way that social theories are used as a means to translate stakeholder interests into designs. This is particularly important for interactive systems with direct human consequences but also for any information system that is used within an organizational or other social context. This view is reflected in the perceptions of many study participants, who felt that the role of social theories in design research is in understanding stakeholders, their activities, and their goals and values.

"…thinking about the interests of stakeholders, who the different classes of stakeholders are, how their interests are represented and what it means, in some sense, conduct socially responsible systems design."

The diversity of theories used in design research is especially apparent in the range of social (and behavioral) theories that are employed to help mold technology to the human context. This was evident even in the perspectives of individual researchers, who sometimes described the routine use of a very wide and inclusive range of reference knowledge.

"From the human side there are a lot of different kinds of theories, qualitative theories of cognition, theories of how people go from what people say about particular phenomena and the kind of grounded theory approach to understanding what are the basic constructs of how they understand an interaction."

and another:

"We try to articulate principles and also we take an interactional view of how people, social systems and artifacts come together and so when we approach a question of solution we look at designing not only the artifact itself but also co-evolving the design of policies and social context of the environment around the artifact and also the context in which it will be used. So the design space is including all of those things."

Some of the ways in which social theories are translated into design specifications are, as discussed earlier, quite opaque. In other cases participants were able to articulate very specific translations of theoretical constructs into designs and artifacts, even in cases where the theory in question is drawn from a purely social domain.

"Judicial theories use the notion of proportionality to balance good against bad and we have tried to take that notion of proportionality and build it into a design method that allows you to up front balance the potential value added propositions of an application against its potential risks."

As some participants pointed out, designs and derived artifacts are inherently social because technology emerges in response to some perceived need for change in the social environment. In turn, technologies adopted for use by people invariably change those people and the social systems in which they exist.

Technical theories suggest solutions

If the primary role of social theory in design is to help understand people and their context, the complementary role of technical theory is to guide designers in the specific envisioning of solutions to address opportunities identified through social analysis. After a problem has been structured and is relatively well understood (using social theory), technical theories suggest approaches to development of solutions that address the problem as represented in domain requirements. An obvious example of this is the way that kernel theories from ISDTs suggest a possible solution to a set of understood domain requirements.

Many of the theories taken from the technical domain prescribe the design and construction of systems according to specific architectural structures including levels, components, and aspects. For example, the model-view-controller architectural pattern was often named as a highly influential *theoretical* idea in the specification of a system's essential form.

"Going back to the design of the implementation itself, you know design patterns we use, are the theory, so the theory of these design patterns are useful. and then we've gone and used the model view controller design pattern, the factory pattern, and so forth."

Some participants' discussions of the use of theory centered on the use of rigorous mathematical, logical, and other formal models to determine the structure and behavior of a system.

"…part of it would be using a different kind of mathematical model to prove that your system is sound, that it scales, no deadlocks, etc."

These formal theories are often predictive, that is, they provide a framework that with adequate and accurate input can predict the quality and presumably the success-in-use of a particular design given a correct problem statement and comprehensive domain requirements.

"So there is one kind of theory which is the classical predictive quantitative theory, Newton, you mentioned at the beginning. You can plug in something you know about a situation and it will tell you something you don't yet know about the situation which may turn out to be verified or not. That kind of theory is what is used in engineering, it is used in a lot of different ways."

and another similar, stronger perspective:

"Other theories I've used extensively, I hesitate to call them theories. it's mathematics. it's theorems. and any good model of designer action or how to represent designs is inevitably a mathematical thing otherwise you can't implement it."

Other participants acknowledged that software and systems design still exhibits attributes of craft-based artisanship derived from long experience with different kinds of problems in varied domains of interest. Though it is unclear how we might incorporate this perspective into theory-led design and development, the work of experienced software developers represents an important resource to the future maturing of the field.

"After 40 years you know what is going to work. To the point where I understand abstraction, use abstraction as a theory. You know modeling in terms of objects, and use that as theory or do modeling in general and try anticipating, figuring out where the boundaries should be, what the proper interfaces should be."

Technical theories may also draw upon so-called non-functional requirements, and this is often a point of intersection with theories drawn from the social domains (e.g., usability, affordability). In such cases theories may be especially useful for suggesting solutions to problems in "wicked" domains (Rittel et al. 1973). These are domains where the range of the solution space is so vast that developers may benefit from the guidance of a structured set of knowledge and prescription for action.

The view of some study participants was that the very purpose of design research is the development of design principles, derived from theory and elaborated, expanded upon, and validated through their application in practice. Related design principles assembled into a coherent system form the basis of an engineering model capable of making predictions about the positive and negative outcomes expected when a particular design technique (structural or behavioral) is applied to a particular kind of problem. Though design principles are intended for application to technical challenges faced in the design process, they are often derived from an understanding of the social and behavioral context in which a design is intended for use.

Theories identify knowledge gaps

One of the classical roles of theories is to structure knowledge in such a way that scientists and other researchers can agree on what is known and what is unknown about a particular domain of inquiry. One manifestation of this in design research is that knowledge gaps are highlighted in a way that suggests opportunities for supporting human activities not currently supported by technology. In more conventional science these opportunities take the form of general research questions or specific hypotheses. Socio-technical theories in particular fuse the parallel notions of knowledge gap and technology gap and provides explicit guidance that design researchers and evaluators can use to apply the "newness" criterion that is often used to judge the value of artifacts in the research context.

Theoretical knowledge gaps perhaps provide one of the most explicit justifications for taking a particular approach to design. As this participant puts it:

"You want to design this way – what is the theory, why you want to do design in this way? What drives you to design this way and not some other way? So there must be something that drives your process or thinking in order to come up with this particular design and they are interested in the theory part."

Gaps in theoretical knowledge are the raw material used in formulating research questions. The more mature and substantial the theory, the more support that can be garnered for taking a certain design stance with respect to its gaps since other theoretical elements constrain and guide the range of possibilities. Theoretical gaps also provide *prima facie* evidence for the newness of a design by how it serves as a first attempt to fill the gap or how it compares to other attempts that have gone on before.

Theory guides reflection on design

One participant discussed how tests of a theory guiding design often occur at the microscopic level and how theory-guided construction talks back to the theory in subtle ways. Repeated positive feedback suggests a theory that is guiding design in positive ways, negative feedback suggests a theory that may not be a good fit, or lack the elasticity to account for continuous shifts in the form of the design. Following a methodology also serves as a kind of theory test, assuming one accepts that methodologies are theories about the best sequence of tasks to employ in the development of information systems.

Theories are not so much an input to the design process as they are a guide to how an artifact can be understood in the context of use.

"Using the theory is never a direct thing, we can often make an argument that we are actually building something that allows reflection, for example, or building something that takes the context into effect and things like that. It is not a lot like theory in computer science where you are basically given the algorithm, and ok, and we go on from there."

Some take a more conventional perspective on the idea of reflection in design, arguing that in the building of a theoretically inspired design we are really testing the efficacy and veracity of the theory itself. Some participants highlighted the fact that by their inherently abstract nature a theory is only really given support when it is able to sustain its usefulness through application in the dirty and *detailed* context of an actual information systems development project.

"A lot of small things appear when you test your artifacts or theories, when you test them in real life."

It may be in the process of reflective design that theoretical ideas are harnessed to better understand and guide an ongoing effort. Reflection is the means through which ideas in the theoretical "idea bank" (discussed above) and more implicit and tacit utility (discussed below) emerge to inform design reasoning.

"But because knowledge is tacit, emerges as a person works and constructs the artifact, each new element of the artifact triggers more thoughts into minds of designers constructing the artifact."

and

"You do a little bit of theory you do a little bit of design and you go back to a little bit of theory and do a bit of design and evaluation fits in like that."

These perspectives point to the way that design-as-research is unique in its ability to act as a concrete instantiation or *nexus* (Carroll et al. 1989) of otherwise abstract socio-technical ideas and o*nly* through design can we achieve realization and subsequent *reflection upon* and assessment of these ideas.

Theory use is often implicit or tacit

Some participants framed their use of theory as a device to inform their perspective towards the design domain. In these types of claims, theory is not used explicitly and directly, construct by construct, but instead provides a sort of *Weltanschauung*, to use a term from soft systems methodology (Checkland 1981), that subtly educates and guides designers in their reasoning about how best to form a solution to a domain problem. In this sense theories act as "soft principles" throughout the design reasoning process.

"…intuitively I am utilizing those concepts knowing that I better make sure I know what the objective is, make sure I know what the context is, etc."

In one of the quotes above, a study participant discussed how translation of the reading of theory to design-in-action can have a long gestation period, in this case 22 years. This is consonant with the constructivist approach, where ideas are absorbed, merged with and expanded by other ideas over time and when circumstances are fertile, emerge as new approaches to addressing concrete design problems.

The extreme of the implicit view is the claim made by some researchers that their design research is entirely independent of theory, and that theory may in fact have no place in the ontology of design.

"I've tried different theories, but I don't find theory very useful in design."

Even in these cases, the comments of some participants suggest that indeed their prior exposure to theory has an effect on the course of their design work.

"I mean it informs things in small ways in the sense of various papers I've read will cause me to maybe lead a brainstorming session in a particular way or it will use it as an anchor for something I'll do but I would have trouble thinking of examples of those, in a way maybe is in the background but it's not explicit."

Participants also acknowledged that what drives their design work is not theory or any explicit principles *per se,* but the whole of their knowledge and experience as derived from both academic and more practice-oriented experience.

"…and I don't entirely know where that insight comes from, it could come from a theory, it could be coming just from practice and familiarity with other systems."

Discussion

One of the goals of the work described here has been to better understand how knowledge, in the form of theories, is translated into design reasoning and action. Though we have been able to elaborate and articulate this process in some new and useful ways, it is clear that we are still a long way from understanding the mechanics of this translation process. It may be that the process will continue to resist attempts at mechanization if, for example, what we are really exploring is the nature of creativity with all its attendant complexity. At some point understanding the use of knowledge in design may mean unpacking the uniquely (or mostly) human trait of creativity and innovation.

The results provide some reusable guidelines for researchers conducting design-as-research. They extend and elaborate ideas presented in the Background section by providing some specific mechanisms researchers can employ both to guide theoretically motivated design of artifacts for research, and to interpret the results of research conducted with a significant design component. For example, in our study veteran design researchers discussed how theories can be used as **idea banks** to guide the specific form that an artifact will take, often by using results from prior work as inspiration for a new approach to an analogous problem domain. More explicitly, theories can help by explicitly identifying **knowledge gaps** where new research programs can progressively contribute to established bodies of knowledge. The apparent interplay between **social theories** and **technical theories** provides fertile ground for mapping solution strategies to acknowledged problems in the social and behavioral sciences.

The apparent distinction between technical and social theories gives rise to questions about socio-technical theory and how it is employed in design research. Is socio-technical theory just the use of social theories co-opted to inform understanding of a particular domain and the human activity that occurs within it? The results above suggest a lack of direct translation from social theory to the choice of theories that inform solutions. The figure below shows a highly simplified view of how social theories may help identify gaps in both knowledge and technology support for human activity within a domain. The fusion of social and technical knowledge in design research results in an artifact, an information system, to represent this theoretical position.

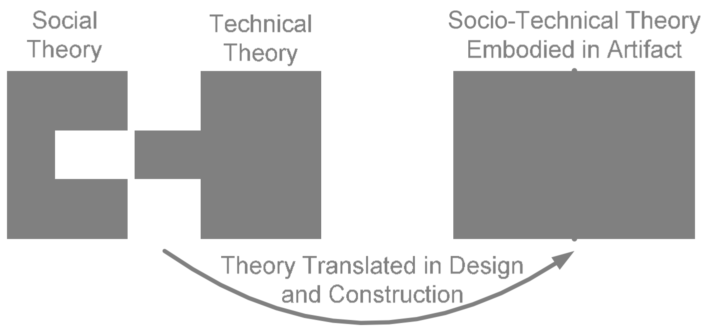

Figure 2 - Social and Technical Theory for Design

Perhaps it is the case that there are not theories that represent both the social and technical in the sense that they each describe a different aspect of design activity: social theories help understand context and people, and suggest gaps in their technology support; technical theories suggest and guides ways of envisioning and creating this support. Or, perhaps it is the case that the socio-technical theory *is the design itself*, the design with its attendant social and technical rationale is the confluence of these very different but complimentary theories.

Some participant discussions in the result section point to a more holistic and nuanced relationship between the social and the technical domains. Technical theories specify solutions but often draw on social phenomena for their motivation and this derivation is often explicit. For example, the model-view-controller (MVC) architecture pattern specifies a particular approach to interactive system architecture. The theory underlying MVC is derived from the idea that *separation of concerns* is a positive attribute of a system and MVC is how designers achieve it. What is interesting and important is that the rationale underlying separation of concerns as a design criterion is based on many non-functional requirements (e.g. usability, reliability, extendibility) that themselves derive from purely social imperatives (e.g. economics, user affect, etc).

That theories act to help direct the translation of domain concepts into working structures is apparent in the views of study participants. Important open questions remain, however, regarding how exactly these translations occur. The perspectives of design science and action research demand more insights into the materials and catalysts that enable shaping of a technology component's structure to best support a particular domain concept or human activity.

Another question that arises from the analysis is whether there are benefits that might derive from researchers having a clear and shared understanding of what constitutes a theory. This point is potentially contentious. For example, is it really constructive to subscribe to a conventional notion of theory as including unobservable elements? Some of the theories discussed certainly include such a construct, for example, Schön's concept of reflection is central to his theory, and this reflection is arguably unobservable except perhaps through introspection. The apparent disparity in understanding of the term *theory* may represent a significant barrier to cross- or even intra-disciplinary communication of knowledge.

A related issue concerns how researchers decide which theory or theories are most appropriate, and which have the most potential to productively influence the design process. A better understanding of the principles or criteria used in design research theory choice would provide support for both novice and experienced researchers as they navigate the large set of theories identified as influencing design, or search for new reference theories that can be translated into design moves.

One potentially problematic aspect of the findings is the degree to which design researchers accept or even promote the idea that theories only *implicitly* inform the conduct of design research. This may be problematic for several reasons but perhaps most importantly because theories act as structured containers for the knowledge that results from a research program, and continuous theory development is considered one way to measure the success of a program (Lakatos et al. 1970). Theories also act as a shared conceptualization for a domain of inquiry, in other words they provide the vocabulary with which researchers communicate about the state of knowledge in their field. These structures and vocabularies make knowledge capture, preservation, and sharing more efficient and thereby contribute to a more progressive accumulation of knowledge about the effectiveness of particular technologies in particular domains of use.

One of the essential attributes of design science and action research is that the artifacts and other solutions that result *should be operational*, in other words, they have to *work*. This unique form of rigor demands that researchers both make use of as much available knowledge, including theoretical knowledge, as is practical to incorporate into a single, cohesive design. It also means that design and action researchers may not enjoy the luxury of single-minded theorizing. Some of the results from the study suggest that explicit coordination and rationalization of all the knowledge brought to bear in development of a working solution is simply beyond the means of any practical design project. Perhaps what is required is some sort of methodological compromise. For example, concepts and tools drawn from the study of design rationale (Moran et al. 1996) might be further developed and leveraged to support more explicit reasoning about the role of theory in design and the results obtained when theories are so applied.

Finally, a prevalent theme in participants' discussions of theory use in design was the apparent domain specificity of theorizing about domains and technology support for human activity within them. This suggests that we are still very far from realizing any sort of general theory of design for information systems. In fact, some participants expressed concern that the goal of this study was to identify a single and general theory of design, and that such a theory might constrain the field in some unproductive ways. Like them, we are skeptical about the possibility of identifying a general theory and, like them, are not sure that such a theory is even a productive goal. Design means many things to people all of whom engage in design for different reasons, with different goals, and with different means. Our objective here is only to explore the space of theory use within the scope of design-as-research and to explicate some guidelines describing how theories are used, and why.

Going forward our aim is to expand the scope of the analysis described here and to begin to answer other questions related to theory use in design research. Specifically, we are interested in how theories motivate undertaking certain kinds of studies; how theoretical propositions are translated into design representations and working systems; and what these representations and working systems tell us about the efficacy of the theories they inscribe. Our overarching goal is not only to contribute to understanding, but to explicate methodological techniques and guidelines researchers can use to guide the use of theory in design studies.

Conclusion

The study and results presented here provides one set of empirical data supporting and elaborating on existing ideas about how theory is used in design research. The contributions claimed should be considered as progressive and integrative rather than as representative of ideas that are entirely new. They provide empirical support for the notion that theory **can** be used within the more practice-oriented sphere of design and action research. They also suggest some ways **how** theories can be used to motivate, guide, and interpret results from research programs that employ design and artifact construction as central to their method of inquiry.

That so many different theories are employed and in so many different ways should not come as a surprise given the range of different ideas and phenomena coming together in information systems and other information technology research. This diversity presents a range of opportunities for researchers interested in understanding how theoretical concepts are translated into working constructs, and how the effectiveness and validity of this translation can be understood and assessed. It also presents some acute challenges to knowledge sharing across disciplines and to a cumulative and progressive science of design. These opportunities and challenges are perhaps especially important in action research, where researchers consciously seek to enact change, often through the creation of new technology, but also see their research as making important contributions in the academic arena. Realizing these opportunities and mitigating the challenges may involve taking on additional responsibilities, including making explicit statements about research objectives, methods, and outcomes relative to the theoretical stance from which they are derived. It may also involve adopting concepts and techniques from design rationale, which entails accepting a significant additional workload in design knowledge capture and management.

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