7-1-2013

Reflection, Abstraction And Theorizing In Design And Development Research

Shirley Gregor
Australian National University, Canberra, Australia, shirley.gregor@anu.edu.au

Oliver Müller
University of Liechtenstein, Vaduz, Liechtenstein, oliver.mueller@uni.li

Stefan Seidel
University of Liechtenstein, Vaduz, Liechtenstein, stefan.seidel@uni.li

REFLECTION, ABSTRACTION, AND THEORIZING IN DESIGN AND DEVELOPMENT RESEARCH[1]

Gregor, Shirley, The Australian National University, Canberra ACT 0200, Australia, shirley.gregor@anu.edu.au

Müller, Oliver, University of Liechtenstein, 9490 Vaduz, Principality of Liechtenstein, oliver.mueller@uni.li

Seidel, Stefan, University of Liechtenstein, 9490 Vaduz, Principality of Liechtenstein, stefan.seidel@uni.li

Abstract

Design theories have been proposed as means to capture abstract knowledge about the design and development of information technology (IT) and information systems (IS) artifacts. There is now an increasingly accepted and used body of knowledge on the processes of design research and the components of design theories. Explicit guidance is still sparse, however, as to how to extract design theories during design science research. In this paper, we focus on reflection and abstraction in design science research as distinct activities leading to design theory. We suggest an abstraction framework that recognizes different modes of causal analysis related to the discrete decisions made by designers and developers as well as to the artifact in use: creative (mental) causes, active causes, and passive causes. The first recognizes the creativity of the human mind, the second deliberate interventions and their consequences, and the third is built upon the notion of affordances that describe the potential uses of an artifact depending on its use context. We argue that these modes of causal analysis can be used to abstract from specific design processes in order to identify key components of design theory.

Keywords: Design Theory, Design Science Research, Theorizing, Information Systems Development, Abstraction, Reflection, Affordances

[1] The authors are listed alphabetically and they contributed equally to the paper.

1 Introduction

Attention has been paid to research processes for capturing and sharing knowledge of the design and development of information technology (IT) and information systems (IS) at least since the "systemeering" approach of Iivari (1983) and the "systems development" approach of Nunamaker, Chen and Purdin (1990-91). There is now a well-accepted body of literature on what is more latterly termed "design science research" (DSR), with a focus on the development of novel and purposeful artifacts (Hevner et al., 2004; Peffers et al., 2007).

When it comes to the role of theory in DSR, Kuechler and Vaishnavi (2012) affirm that theory can be both an input to design (kernel theories, design-relevant explanatory/predictive theories) and an output of design (design theories). Design theories as outputs of design science research, which are in the focus of this article, give explicit prescriptions on how to design and develop an artifact that accomplishes some end (Baskerville & Pries-Heje, 2010; Gregor & Jones, 2007; Walls et al., 1992). Through design theories important lessons learned both in research and practice can be captured and shared widely, with consequent valuable benefits to industry and society. There is an increasingly accepted and used body of knowledge on the structural components of design theories in information systems research (Baskerville & Pries-Heje, 2010; Gregor & Jones, 2007; Walls et al., 1992). Still, comparatively little guidance is available as to how to develop design theories based on design science research. There are examples where design theories were developed by logical deduction (e.g. Müller-Wienbergen et al., 2011), but less is known about design theorizing through inductive processes of reflection and abstraction. Thus, our research question is:

> *How can design theory be developed through abstractive and reflective activities in design science research?*

In answer to this question, we propose a framework for abstraction and reflection in design research that is linked to basic components of design theory. Here, abstraction refers to the process of deriving abstract concepts (e.g., generic features) from observed instances (e.g., instances of a class of artifacts). Reflection, in broad terms, refers to contemplating about, and learning from, experiences made in the past. Together, these mental activities offer the potential to generate generic knowledge out of design practice. Our focus is on the abstractive and reflective activities that occur when theory is being formulated, rather than the whole cycle of activities in DSR. The abstractive/reflective activities can take place throughout the DSR cycle and can be performed by the designer/developer, or by an external person.

We ground our work in the idealized model of the design theorizing process presented by Lee, Baskerville, and Pries-Heje (2011), who show that design theorizing operates in two domains, an instance domain and an abstract domain. While these authors identify four main activities in design theorizing, namely abstraction, solution search, de-abstraction, and registration, there is still a lack of detail as to how these activities can be undertaken. We further draw upon literature on functional creativity (Cropley & Cropley, 2010), concepts of causal analysis (Gregor & Hovorka, 2011), and the concept of functional affordances (Markus & Silver, 2008) to underpin our framework.

The remainder of this paper is structured as follows. First, we provide the research background, focusing on fundamental concepts of design theory and theorizing, causal analysis, and reflective processes. Second, an interlude provides a simple example of the important points and terminology in our paper using a class of common household artifacts (jugs). This is followed by the presentation of our framework for abstractive and reflective activity in design theorizing, with examples of how design theorizing has occurred in illustrative cases. We then discuss our findings and provide a conclusion.

2 Design Theorizing

With regard to theorizing in DSR, a number of researchers have proposed ideas, frameworks and guidelines for constructing design theories. However, much work on DSR does not explicitly distinguish the theorizing or reflective steps from an overall process of DSR (e.g., Hevner et al., 2004; Peffers et al., 2007).

Goldkuhl (2004), for example, argues that design theories should be grounded in relation to multiple sources of knowledge, namely, external theories (theoretical grounding), empirical data (empirical grounding), and the design theory itself (internal grounding). With regards to the theoretical grounding, design can be deductively derived from other already existing theories. With regards to the empirical grounding, design theories can be generated through explicit modification (changing theories based on application and observation), tacit induction (emergence of tacit action rules based on experiences), or articulated induction (reconstruction of action rules from practice). Finally, with regards to the internal grounding, design theories can be developed from the inside without any external input by continuously introducing and refining of ideas and constructs.

Lee et al. (2011) present an idealized process for creating design theories. The proposed theorizing process operates in two distinct domains (abstract domain and instance domain), comprises two main constructs in each domain (problems and solutions), and four theorizing activities (abstraction, solution search, de-abstraction, registration). In particular, the authors outline how to move from the instance domain to the abstract domain through reflective judgments (i.e., searching for unknown universals for given particulars) and from the abstract domain to the instance domain through deterministic judgments (i.e., subsuming given particulars under known universals). In addition, the role of different reasoning logics in design theorizing is discussed. While the authors acknowledge the relevance of deductive and inductive reasoning in design theorizing, they argue that creating design theories is a predominantly abductive process and involves intuitive and creative thinking.

Kuechler and Vaishnavi (2012) propose a framework to support the development of different kinds of theories in DSR. The framework contains a hierarchy of three different types of theories (kernel theories, design-relevant explanatory/predictive theories, information systems design theories) and three general activities of theory development in DSR (construction of an artifact informed by theory or practice-based insight, gathering of artifact performance data, reflection on the construction process and the gathered performance data). They briefly touch upon the role of different ways of thinking about design (deduction, induction, abduction, triangulation of perspectives, circumscription, analogical reasoning, reflection) in the course of design practice processes and how these may lead to theory construction opportunities.

Fischer, Gregor, and Aier (2012) analyze the differences between inductive and abductive design research, and also discuss the impact of the two forms on validity, utility, generality, and innovativeness of the design artifacts. Inductive discovery is data-driven, whereas abductive discovery is based on existent theories as well as knowledge. It is further argued that pure deduction can never lead to new knowledge. Still, “background theories play an important role in abduction.” They note that design knowledge is generated based on either inductive or abductive reasoning, or both. Based on inductive and analytic reasoning, the researcher can infer design knowledge about a class of artifacts grounded in the empirical data from the processes of design, development, and evaluation.

The above exemplars of design theorizing, and design theorizing processes, show that there is some agreement on the relationships between conducting design work and design theorizing. The extraction of design theory through a process of abstraction and reflection can be grounded in different forms of reasoning. Design theorizing may rely on deductive (based on prior design-relevant theory), inductive (based on observation of actual design processes), and abductive (based on making sense of observations by referring to prior theory) reasoning. However, it is still unclear how exactly the design researcher can reflect upon the conducted design and development work in order to extract design theory.

3 Conceptual Foundations

In this section, we explain some foundational concepts that help us to understand design theory and theorizing, namely domains of design research, components of a design theory, activities in identifying design theory, and modes of causal analysis in design theorizing.

Domains in Design Theorizing

The high-level framework that gives a base for our discussion is provided in Lee et al. (2011), which shows two distinct domains (abstract domain and instance domain), with two main constructs in each domain (problems and solutions). We will adopt this terminology, while noting that there can be many layers of abstraction. The step we are particularly interested in this model is the "abstraction" step—going from instance problem and instance solution to abstract problem and abstract solution. This step requires reflection on the design process.

Components of Design Theory

We consider the nature of generic design knowledge (the abstract domain) by looking at the basic components of design theory, as in Gregor and Jones (2007): The *purpose and scope* describe what the artifact is good for (i.e., its goals or meta-requirements) and thus also, by inference, what it is not meant for. *Constructs* are the design "concepts" underlying the artifact. *Principles of form* represent the structure of the artifact (i.e., its shape or architecture). *Principles of function* represent the functioning of the artifact (i.e., what it does when in action). In this paper, we will focus on how purpose and scope as well as principles of form and function can be extracted based on reflective and abstractive activities; constructs are needed in order to express these. With regard to the principles of form and function, we are interested particularly in the difference between essential form and function components (in both the abstract and instance domain) as opposed to arbitrary form and function components. As Lee et al. (2011) write: "It is the uncertain nature of design problems that calls for reflective judgment to decide which essential conditions are applicable to a broader class of problems than just the one at hand" (p 8). Other components of a design theory (justificatory knowledge, artifact mutability, testable propositions, principles of implementation, and expository instantiation) are touched upon in our discussion but are largely outside the current scope.

We note further one aspect of design activity that is relevant to our discussion but has not previously been linked to design theorizing. Studies of designers at work show that an early stage of designing is the development of a key design concept, a high-level mental representation of the relationship between a problem formulation and an idea for a solution. Creative design is then a "constant iteration of analysis, synthesis and evaluation processes between the two notional design 'spaces'—problem space and solution space" in a process of "co-evolution" (Dorst & Cross, 2001 p 434). In this essay, we refer to an important high-level insight into a potential design solution as a "design concept" or a "design idea."

Identifying Components of Design Theory—Abstraction and Reflection

Both abstraction and reflection are needed in order to extract generic knowledge from design processes and develop design theory.

Abstraction is the process through which the researcher moves from the instance domain to the abstract domain, thereby identifying more general knowledge (Lee et al., 2011). This process is closely related to that of reflection, or reflective judgment, which forms the basis for abstraction (Lee et al., 2011). Citing Kant (2000), Lee et al (2011) write: "This process of abstraction essentially involves reflective judgment where unknown universals for given particulars are sought" (p 7).

Reflection is a way of learning. In broad terms, it refers to contemplating about experiences made in the past. Daudelin (1996) describes it as "the process of stepping back from an experience to ponder, carefully and persistently, its meaning to the self through the development of inferences" (p 39). Reymen (2001), based on an analysis of the concept of reflection in different domains (e.g., computer science, management), developed a definition of reflection in the context of design: “Reflection on a design process means an introspective contemplation of the designer’s perception of the design situation and of the remembered design activities” (p 32). These definitions illustrate that reflection is a highly personal cognitive process that is often spontaneous and sometime even outside of an individual’s awareness (Daudelin, 1996). However, reflection can be triggered by certain practices and tools. Posing and answering questions about observations and experiences is known to be one of the most powerful techniques to foster reflective learning (Daudelin, 1996). Posing questions on a design problem, for example, helps to identify differences between the current and desired form and function of an artifact and to understand important design context factors (Reymen, 2001) . Posing questions on the remembered design activities helps in identifying which activities were successful in reaching the design goal, or—maybe even more importantly—sorting out unsuccessful design activities (Reymen, 2001). Another tool to facilitate reflection is a notebook that records successive attempts at solutions (Daudelin, 1996). This way, the researcher can document successful solutions as well as unsuccessful solutions along with potential explanations. Identifying successful and unsuccessful attempts in solutions will require the researcher to embark on a process of counterfactual reasoning, thereby understanding the cause-effect relationships involved in the design artifact. Reflection in design theorizing works on two levels: reflection on the IT/IS artifact in use and reflection on the discrete design decisions made by the designer.

Causal Analysis in Design Science Theorizing

We find it useful to look at causal reasoning in respect of design theorizing and part of reflective and abstractive activity. After all, theories are expected to explain when, why, and how something happened, meaning that we are looking at the cause, or constellation of causes, that lead from one state of affairs to another. It is therefore essential that we understand the **causal reasoning underlying specific design decisions** that are made by a designer as well as the **causation related to the IS/IT artifact in use**. We focus on three different types of causation that are susceptible to causal analysis in design theorizing: creative (mental), manipulation (active), and enabling (passive) causation (Gregor & Hovorka, 2011). The three different types of causal analysis in theorizing may be intertwined, and are not mutually exclusive.

Creative causation refers to the case where mental activity brings about change: that is, a designer conceives of some new way of doing something and is then able to put those ideas into action. This creative causation is a type of mental or substantival causation as described by Kim (2011). Goldkuhl (2004 p 68) uses the terms “inside development” and “idea based design” to refer to similar concepts. It is important to recognize this concept of causation because it can be one of the most significant parts of design research—the source of novelty. For instance, the first decision support system would not have come about if Scott-Morton (1967) did not have the initial design idea that envisaged the possibility of such an artifact. This mental activity is recognized in the creativity literature under labels such as “incubation,” where ideas churn in a person’s head, and “illumination,” where what seems to be a solution becomes apparent (Cropley & Cropley, 2010 p 309). “Preparation” activities include the accumulation of general and specific knowledge in the problem area. Subsequent design activity involves “verification,” where the apparent solution is investigated: as in translated into a functioning artifact.

In analysis of active causation we can study acts or interventions or steps in a process where deliberate intervention brought about change. It thus relates to manipulation or intervention analysis (Gregor & Hovorka, 2011): the design is grounded in the understanding that an IS/IT artifact or human agent acts (manipulates) to cause an effect, a change in outcome. The change would not (or is very unlikely) to have occurred without that agent’s action. This analysis may be relatively straightforward in some cases. For instance, in a computer program one can see that a set of programming commands must be enacted to bring about a desired effect and the analysis of the necessity for all the commands may be amenable to logical analysis (as in a theorem prover). The situation may be more difficult in a situation involving human intervention in socio-technical systems. For instance, in adopting a particular systems development methodology it may be difficult to disentangle the effects of enacting the steps in the methodology from other contextual conditions, such as, the skills of a particular development team. In these cases, the type of reasoning known as counterfactual analysis may be used: What appears to be the key difference in one case as opposed to other possible comparable cases (Pearl, 2000)? This is the type of analysis used in experiments where, however, more control over other possible explanations of outcomes is possible.

Passive causal analysis relates to enabling causal condition analysis (Gregor & Hovorka, 2011): the change in outcomes is enabled by an artifact's characteristics along with contextual conditions. These conditions are not sufficient in themselves, however, to bring about an outcome without some action being taken. In analysis of passive causes, one can use the concept of functional affordances (Markus & Silver, 2008). Functional affordances are defined as a relation between technical objects (viz., the material properties of technical objects or specific systems features) and user groups. That is, the effects of IT artifacts are viewed to depend on their context of use (Markus & Silver, 2008). Functional affordances, therefore, describe the action possibilities provided to specific user groups by material properties existent in technical objects (Leonardi, 2011). For instance, a menu icon allows the possibility of a user clicking on that icon to call a sub-menu, given the user is capable of clicking and understands what the icon is for. Therefore, functional affordances provide an adequate lens in order to study passive causation in design science research. Passive causation is rooted in enabling causal condition analysis: the change in outcomes is caused by an artifact's characteristics along with enabling contextual conditions (use context) (Gregor & Hovorka, 2011).

4 Interlude—A Simple Illustration

We chose a simple class of artifacts to ground our arguments regarding reflection and abstraction. Consider the design of the class of artifacts known as jugs. It seems some cultures never invented jugs, so there is nothing predetermined about their existence—they came from human creativity. A jug may take many forms, as in Figure 1. Initially, there must have been a **design idea** for the first of an artifact of this type, occurring in the abstract domain. Perhaps a creative thought struck a potter who was experimenting when making simple vessels. The design idea would be something like: If I add a "handle" and a "spout" **(constructs)** to a container with an opening then I have a better artifact for pouring liquid **(purpose and scope)—**a jug. This mental process is an example of **creative causation** in design. Based on the designer's general knowledge about a domain (here: pottery) a first design idea is formed. In many cases, this idea is based on transferring, refining, extending, and/or combining already existing concepts from one or multiple fields into a new creative product (Cropley & Cropley, 2010). Only seldom something fundamentally new is developed. Also note that, despite well-known anecdotes of "eureka"-moments, in most cases the design idea does not come out-of-the-blue, but usually incubates in the designer's mind for quite a long period of time (Cropley & Cropley, 2010). Creating the first tangible jug would then be the proof-of-concept (instance domain) of the design idea.

(a) (b) (c) (d)

Figure 1: Different instances of the artifact class "jug" (Source: Wikimedia.org)

The designer, or others, may define some central design principles for jugs. These principles are core to the conceptualization and requirements of what it means to be a jug:

1. Choose a shape that has the capacity to hold liquid.
2. Provide an opening through which liquid can be added.
3. Provide a feature that allows liquid to be poured (i.e., a spout), which can be contiguous with the main opening, or not.
4. Provide a feature that allows it to be picked up by a human (i.e., a handle).
5. Ensure it is of a suitable size and weight when full to be lifted and manipulated by a human.
6. Ensure that the jug can stay upright on a horizontal surface.

The above principles appear to be essential principles for something to serve as a jug and are **principles of form**. Note that the jug could be square, or cylindrical, or short and squat, or tall, or have a lid, or be made of metal, plastic, or china—these are all arbitrary features.

Other principles can be advanced by studying different types of jugs and their use in different conditions and considering justificatory knowledge including everyday knowledge of the behavior of liquids and the laws of physics. For instance, in order for a jug to be effective and useful:

7. Place the handle opposite the spout in order to get maximum leverage.
8. Ensure that the spout of the jug is above the highest point at which liquid can be held in order to make maximum usage of capacity.

Note that the jug in Figure 1 (d) contravenes principles 7 and 8, for the specialized purpose of beer drinking.

One could infer more principles from experimenting with the artifact, watching people use it. For instance, the overall **principles of function** to use the jug:

1. Add liquid through opening (the opening that is not the spout).
2. Lift jug by handle.
3. Tilt jug and pour liquid out through spout.

The two sets of principles are extracted by analysis of both passive and active causes. Finding justificatory knowledge that supports the argument that a specific design characteristic assists with the achievement of a certain goal (as in the handle being a shape that suits the human hand) helps separate essential design principles from arbitrary ones.

The principles of form (the shape of the artifact) can be identified by **passive causal analysis**, that is, affordances. Some affordances may have been deliberately designed by the designer. For example, the designer knows from knowledge of mechanics (or prior design experiences) that the handle needs to be opposite the spout for maximum leverage (unlike Figure 1(d)). Observing how people use a jug can uncover other potential affordances proffered by the jug's material properties. For example, one could observe that in some situations people use both the spout and the main opening—if there was one—to fill the jug with water or pour water out of the jug. Or, one could observe that people use the jug to store other things than liquids, for example, powder or granular materials. These insights may lead to changes to the original principles of form, for instance, making the spout big enough to allow for pouring granular materials (e.g., grains).

The principles of function can be identified by **active causal analysis**. How does the artifact operate to achieve its goals? Providing enabling conditions (affordances) is not sufficient, as some action needs to occur for the jug to be used. Our analysis, which is actually of the human-jug system, shows the sequence of actions that need to be performed to use the jug: that is, filling, lifting, tilting, and pouring, as above. These principles of function are identified partly by counterfactual analysis: as in, the liquid will not pour out unless the jug is tilted. The order of the actions is in part a matter of common sense reasoning but is also congruent with knowledge of physics.

This example may seem labored but it shows effectively, if informally, how design principles can be extracted through reflection and abstraction. In the next section, we consider the problem more formally.

5 A Framework for Reflection and Abstraction in Design Theorizing

In this section, we suggest a framework for reflective and abstractive activities in design theorizing, followed by some illustrative examples in system development work. Table 1 shows the framework that links design theory components, abstraction activity and some possible reflective questions. The framework is based on prior literature and the use of causal analysis in work in which the authors have engaged. We do not claim that this framework is exhaustive, and other means of abstraction may be possible.

Table 1: Framework for Extracting Design Theory

Design Theory Component	**Abstraction Process**	**Reflective Questions**
Purpose and Scope	Identify the high-level meta-requirements or goals of the artifact. This identification can be assisted by reflecting on the original problem-solution space. The requirements may have been specified to the designer/developer, or a novel design idea may have been generated by the designer, requiring creative causal analysis.	*What was the problem the researcher originally perceived? Was the problem generated by the researcher or provided by someone else? What is the goal of the artifact?* *How did the original design idea come about? Can you give the design idea a name? Naming the concept can help thinking about it and its distinct properties as a class of things.* *What concepts formed the basis for the first tentative design? From which fields did these concepts come? Why exactly these?* *Were there subsequent problems that emerged? Did they require further innovative design ideas? What else was important?*
Principles of Form	Identify the architectural aspects (the form) of the artifact that facilitate the achievement of its goals. Identifying these architectural aspects can be assisted by reflecting on the affordances that the artifact offers, and why they work, and thus requires passive causal analysis. The analysis may be assisted by considering original or subsequent design ideas (creative causation) that are core to the linkage of design characteristics with achievement of goals.	*What material properties did the designer deliberately build into the artifact to enable it to achieve its purpose?* *What material properties of the artifact in use are observed to contribute to the emergence of the desired affordances?* *What contextual conditions are observed to enable the emergence of the desired affordances?* *Which user groups perceive which functional affordances of the artifact?* *What changes are required in the essential material of the design artifact or in the enabling contextual conditions in order to lead to the emergence of desired functional affordances?* *What justificatory knowledge provides support for the linking of the material properties to the achievement of the artifact's goals, as originally envisaged, or arising in use?*
Principles of Function	Identify the series of actions that is necessary (or close to necessary) for the artifact to achieve its goals, possibly as part of a wider artifact-actor system. Identification can be assisted by reflecting	*Which acts or interventions have to be performed in order to reach a specific goal?* *Who is the agent?* *In what order should the actions be undertaken?*

	on active causation—analyzing acts or interventions by an agent (human or otherwise), or agent acting with the artifact, in a context where the act has an observable outcome. The analysis may also be assisted by considering original or subsequent design ideas (creative causation) that are core to the linkage of design characteristics with achievement of goals.	*What are the observed effects?* *Which actions are necessary (or most necessary) to bring about desired outcomes? Why are they necessary (is there underlying support from justificatory knowledge)?* *Which actions are incidental to the outcome (where some other action could likely serve the purpose just as well)?*

We will discuss the three modes of causal analysis, in turn, with examples of design science reflection and abstraction. Note again that we stress these analyses do not occur independently and in many or most cases all types of analysis would be used together. Our examples illustrate activities in which one type of reasoning predominates. Two of the examples are from work in which the authors or colleagues have applied the questions in the framework to develop design knowledge. However, space restrictions in this paper preclude a detailed description of how the questions were used.

5.1 Reflection on Purpose and Scope and Creative Causation

Creative causation analysis focuses on the design conceptualization that occurs in the first phases of creative functional design (Cropley & Cropley, 2010), where there is awareness and knowledge of problems and a candidate solution is conceived. In creative causal analysis we, or the inventor, have to reflect back on the origins of their ideas for an artifact. What was the original design concept? This analysis may be helped by keeping notebooks throughout the design process and documenting and examining early attempts at solutions. This, in turn, allows us to identify the **design idea** underlying the designed artifact. Note that the early design idea can be of tremendous importance as the basis for a claim for novel contributions to design theory. At this, reflection on creative causation relates to reflection on idea generation and discrete design decisions, as opposed to the artifact in use.

Novel design ideas and the central concepts of a new design can be identified in journal articles. For example, Albert, Goes and Gupta (2004) present an artifact named GIST that supports customer relationship management web sites. They state, in highlighting the research contribution, that:

> *We create a new knowledge artifact by defining the* ***concept*** *of the nanosegment and its relative positioning in the traditional consumer segmentation approaches. We also present the* ***idea*** *of gap analysis to internalize the design of a feedback loop for continual evaluation of the managerial artifact, the Web site, to identify and process redesign needs via gap analysis.* (p 165, emphasis added).

Personal experience has shown, unfortunately, that often a researcher, having labored through the difficulties and lower level design decisions needed to achieve an artifact that will work, has difficulty in recalling or recognizing the first design idea or design "vision" that underpinned the work. If the underlying design concept can be resurrected, it often indicates how the important contributions the work makes can be framed. It is here that keeping notebooks and records of successive attempts is of tremendous importance.

An example comes from design science research in industry that has created a new enterprise architecture modelling framework that has been used successfully in two case studies and is now called the Complexity Analyser Toolkit (CAT[7]) (Brad McCusker, pers. comm., 23 Nov., 2012). The researcher was asked to reflect on how the original idea for his artifact came about:

> *Having completed TOGAF certification, I was unsatisfied that despite a 2000 page document, TOGAF did not address a range of complex issues in Federal government. So I thought what I had to do was come up with a method that joined in other domains to TOGAF and better addressed the complexity issues. I had an initial idea of EAOF (Enterprise Architecture Optimizer Framework) that included more things that needed to be included when planning in*

> *an EA environment. It needed to give a unified view of knowledge of key things (strategic knowledge, resource allocation, citizen views, hardware and software requirements and so on) and the inter-relationships between them. It needed to have the citizen as the start point and the other start point as the strategy. No other EA framework is as holistic—inclusive—and also shows directional flows.*
>
> *The basic concept was built on using the idea of fractal patterns, a layered set of models to deal with problems. Now (2 years later) it is very difficult to identify looking at* CAT[7] *what the original design concept was. It's morphed. You can see how the design changed in five major iterations, with building around the starting point.* (Brad McCusker, pers. comm., 23 Nov., 2012).

5.2 Reflection on Principles of Form and Passive Causation

In passive causal analysis we, or the inventor, have to reflect on discrete design decisions that were made in order to meet some ends within some contextual setting. Reflecting on passive causation, therefore, means analyzing the affordances that are provided by an IS/IT artifact in a relation to a specific use context. That is, in the context of design research, affordances provide an explanation of why certain material properties facilitate a consequence, or are perceived to facilitate a consequence (Markus & Silver, 2008).

In design theorizing the researcher needs to abstract the material properties that the designer gave to an artifact away from the implementation details. Likewise, the researcher needs to identify conditions of the use context that enable the emergence of specific affordances for particular user groups.

Markus and Silver (Markus & Silver, 2008) provide an example:

> *"[A group support system] may afford groups that want to make consensus decisions the opportunity to surface ideas anonymously and tabulate the results of straw polls quickly. The same system may afford nothing to a team run by an autocratic leader, whose goal is to avoid surfacing dissenting opinions, or to a team lacking access to a group facilitator or skills in using group process tools"* (p 622).

In passive causal analysis we, or the inventor, would ask*: What are the essential material properties that the designer gave to the artifact so that it would allow to surface ideas anonymously? What user groups perceived this affordance? What enabling conditions lead to the emergence of the affordance?* Thereby, it is possible to describe what generic material properties (e.g., anonymous use, idea generation, electronic voting) created what affordances (surfacing ideas anonymously) for which user group (democratic groups) enabled by what contextual conditions (availability of a group facilitator).

5.3 Reflection on Principles of Function and Active Causation

Reflecting on active causation means analyzing acts or interventions by an agent (human or otherwise) in some context where the act has an observable outcome. As such, this type of analysis is suited to analyzing the trajectory of change when an artifact is in use. It appears most suitable for extracting design principles of function, as in process-type artifacts (a change intervention, an algorithm) or the methods for using product-type artifacts (a jug, a modeling tool). Design principles of function give the order of steps or actions in a process, as in the steps of a system development methodology (Gregor and Jones, 2007). In some cases, for instance with an algorithm, the artifact will be used in relatively closed systems and the design principles will be general and high-level. In other instances, for example a change management method, the principles may need to be adapted for use in specific contexts.

In design theorizing the researcher needs to get the key parts of the artifact (e.g., an algorithm or a change management method) abstracted away from the implementation details.

An example is provided by Gregor, Imram and Turner (2010) in a report of a change strategy implemented in Bangladesh over 12 months to encourage e-government adoption. These authors present the meta-level project principles they felt were the key factors responsible for the positive outcomes from the project. The primary design principle was: *Identify and act on the Sweet Spot(s). Search for and identify the primary underlying inhibitor(s) for a desired outcome and target the initial intervention activity to address and overcome the primary inhibitor(s)* (p 18). This primary design principle captures the original design idea that motivated their action research project. It was originally thought of by other names such as “unlocking the logjam”. Subsequently it found support in ideas from complex systems and was renamed as the “Sweet Spot Principle.” Other support principles were also identified for change in e-government in a least developed country. These support principles were identified by an explicit process of counterfactual analysis to identify key design principles that had the highest “probability of necessity” (Pearl, 2000). They included: *Engage influential stakeholders* and *Tailor the intervention to suit the LDC* (*least developed countries)* (p 18).

6 Discussion and Conclusions

In this paper, we set out to shed some light on reflective and abstractive activities in design theorizing. We argued that these activities can draw on different types of causal analysis, most notably, creative causation, passive causation, and active causation. While creative causal analysis allows us to identify the underlying design idea and its purpose and scope, passive causation allows us to identify principles of form through studying how material properties create specific affordances in specific use contexts, and active causation to identify principles of function through studying the consequences brought about by deliberate acts and interventions.

One issue that has remained untouched in this essay is the discussion of the nature of design theory that can be generated based upon the different types of causal analysis in reflective and abstractive activities. Design theory that is created based on reflection and abstraction of IS/IT artifacts, one may argue, is substantive in nature as it is bound to the context that is studied. This appears to particularly be the case in passive causal analysis, where the researcher identifies material properties that bring about affordances in relation to a specific use context. However, also in the case of active causal analysis, one will have to question to what extent the observed consequences depend on the use context. Still, investigating many instances in multiple contexts may help the researcher to proceed to more general, or even formal design theory (Urquhart et al., 2010). Besides, one may argue that the level of abstraction that can be reached based on the reflection of specific instances will much depend on the nature of the artifact. Abstracting away from the implementation details of an algorithm will lead to more formal design theory than abstracting away from the implementation details of a change management method which, by its very nature, will depend on the context it is deployed in.

The paper presents a framework that the authors have found useful in their own work and in assisting research students to abstract design knowledge from their research projects. Future work is proposed that will investigate the usefulness of the framework to others and show whether, and how, the questions in the framework help researchers uncover contributions to design theory.

References

Albert, T., Goes, P. and Gupta, A. (2004). Gist: A model for design and management of content and interactivity of customer-centric websites. *MIS Quartrely*, 28 (2), 161-182.

Baskerville, R. and Pries-Heje, J. (2010). Explanatory design theory. *Business and Information Systems Engineering*, 2 (5), 271-282.

Cropley, D. and Cropley, A. (2010). Functional creativity “products” and the generation of effective novelty. In *The cambridge handbook of creativity* (Kaufman, J. and Sternberg, R., Eds), pp 301-317, Cambridge University Press, Cambridge.

Daudelin, M. (1996). Learning from experience through reflection. *Organizational Dynamics,* 24 (3), 36-48.

Dorst, K. and Cross, N. (2001). Creativity in the design process: Co-evolution of problem-solution. *Design Studies,* 22 (5), 425–437.

Fischer, C., Gregor, S. and Aier, S. (2012). Forms of discovery for design knowledge. *European Conference on Information Systems*, Barcelona, Spain.

Goldkuhl, G. (2004). Design theories in information systems - a need for multi-grounding. *Journal of Information Technology Theory and Application,* 6 (2), 59-72.

Gregor, S. and Hovorka, D. S. (2011). Causality: The elephant in the room in information systems epistemology *19th European Conference on Information Systems*, Helsinki, Finland.

Gregor, S., Imran, A. and Turner, T. (2010). Designing for a ‘sweet spot’ in an intervention in a least developed country: The case of e-government in bangladesh. *SIG GlobDev Third Annual Workshop,* Saint Louis, USA.

Gregor, S. and Jones, D. (2007). The anatomy of a design theory. *Journal of the Association for Information Systems,* 8 (5), 312-335.

Hevner, A. R., March, S. T., Jinsoo, P. and Ram, S. (2004). Design science in information systems research. *MIS Quarterly,* 28 (1), 75-105.

Iivari, J. (1983). *Contributions to the theoretical foundations of systemeering research and the picoco model.* Institute of Data Processing Science, University of Oulu, Oulu, Finland.

Kant, I. (2000). *Critique of the power of judgment.* Cambridge University Press, Cambridge.

Kim, J. (2011). *Philosophy of mind,.* Westview Press, Boulder.

Kuechler, W. and Vaishnavi, V. (2012). A framework for theory development in design science research: Multiple perspectives. *Journal of the Association for Information Systems,* 13 (6),

Lee, J. S., Pries-Jeje, J. and Baskerville, R. (2011). Theorizing in design science research. *6th International Conference on Design Science Resarch in Information Systems and Technology (DESRIST)*, Milwaukee.

Leonardi, P. M. (2011). When flexible routines meet flexible technologies: Affordance, constraint, and the imbrication of human and material agencies. *MIS Quarterly,* 35 (1), 147-168.

Markus, M. L. and Silver, M. S. (2008). A foundation for the study of IT effects: A new look at DeSanctis and Poole’s concepts of structural features and spirit. *Journal of the Association for Information Systems,* 9 (10), 609-632.

Müller-Wienbergen, F., Müller, O., Seidel, S. and Becker, J. (2011). Leaving the beaten tracks in creative work - a design theory for systems that support convergent and divergent thinking. *Journal of the Association for Information Systems*, 12 (11), 714-740.

Nunamaker, J., Chen, M. and Purdin, T. (1990-91). Systems development in information systems research. *Journal of Management Information Systems,* 7 (3), 89-106.

Pearl, J. (2000). *Causality.* Cambridge University Press, Cambridge, UK.

Peffers, K., Tuunanen, T., Rothenberger, M. A. and Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems,* 24 (3), 45-77.

Reymen, I. M. M. J. (2001). Improving design processes through structured reflection: A domain-independent approach. *SAI Reports*, Eindhoven, The Netherlands.

Scott-Morton, M. (1967). Computer-driven visual display devices – their impact on the management decision-making process. Harvard Business School.

Urquhart, C., Lehmann, H. and Myers, M. D. (2010). Putting the ‘theory’ back into grounded theory: Guidelines for grounded theory studies in information systems. *Information Systems Journal,* 20 (4), 357-381.

Walls, J., Widmeyer, G. and El Sawy, O. (1992). Building an information system design theory for vigilant EIS. *Information Systems Research,* 3 (1), 36-59.