The Empirics of Design Research: Activities, Outcomes and Functions

Completed Research Paper

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Abstract

Design research (DR) has matured as an important research approach within information systems. It can be seen as a response to the quest of more focus on the IT artefact. Besides the IT artefact, there are other important artefacts to build and study in DR. There are models and prototypes which are produced during information systems development. This paper has investigated the empirics of design research, especially activities and outcomes. Based on a conceptual inquiry of design research literature and two cases of design research, a conceptual clarification of design research empirics has been established. Two cases of public e-service design form the empirical bases for this conceptual development. The empirics of design research (i.e. a design practice) is distinguished from the theorizing part of DR. Empirical data of DR to be used for theorizing consist of produced artefacts, embedded data collection for design and theory-required data collection. Three types of evaluation in DR are distinguished: Embedded evaluation in design activities, explicit formative evaluation with data from use settings and theory-required evaluation in order to assure theoretical validity of results.

Keywords: Design research, design practice, empirical data, model, prototype, theorizing, evaluation, public e-service

Introduction

Since long ago, many information systems (IS) scholars have had an interest for "knowledge in making". Different methods, models, tools and IT artefacts have been produced in research endeavours. The legitimacy for this kind of research has grown dramatically through the articulation of design science/design research (DR) as a distinct research approach within IS (e.g. Nunamaker et al, 1991; March & Smith, 1995; Hevner et al, 2004; Hevner & Chatterjee, 2010). The introduction of DR has helped many scholars to choose this as an appropriate research approach and to adapt it to their research purposes.

We are in the era of design research emergence. DR is being applied and DR is being debated. There exist several controversies within DR. One is the issue of theorizing in relation to DR. Should we conceive theory as a result of DR or is theory generation considered to be a related but external activity (Walls et al, 1992; Gregor & Jones, 2007; Hevner et al, 2004)? The notion of design theory is considered controversial and there exist several views on what constitutes a design theory (Walls et al, 1992; Goldkuhl, 2004; Venable, 2006; Gregor & Jones, 2007; Baskerville & Pries-Heje, 2010; Lee et al, 2011; Kuechler & Vaishnavi, 2012). There are objections to a limited "build and evaluate" view on DR as it appears in Hevner et al (2004). There are arguments and conceptions to bring theorizing activities into DR (Venable, 2006; Winter, 2008; Goldkuhl & Lind, 2010; Lee et al, 2011). From this follows controversies of what is considered as empirics in DR. Is artefact design an empirical activity or is it just the data gathering around the artefact that should be considered as empirical activity (Hevner & Chatterjee, 2010; Goldkuhl & Lind, 2010)? A main idea about data collection in DR is to generate data that can be used for evaluation of the designed artefact. There exist also controversies and different views on evaluation as parts of DR (Sein et al, 2011; Venable, 2012; Papas et al, 2012; Sonnenberg & vom Brocke, 2012). For example, what should we evaluate; when should we evaluate; and how should we evaluate? Originally, there were four types of outcomes (artefacts) considered to be the results of DR (March & Smith, 1995; Hevner et al, 2004): Constructs, models, methods and instantiations. However, there are objections against this ensemble, since it cuts through an abstract – concrete dichotomy (Goldkuhl & Lind, 2010).

There are obviously needs for further conceptual development of design research as an approach within IS. All the mentioned issues will not be addressed in this paper. Some will be addressed thoroughly, while others will be only touched upon. The main focus will be on the empirics of design research. This focus will bring different issues together in a conceptual inquiry. *The purpose is to contribute to a conceptual development and clarification of DR as an empirical research approach within IS.* The pending research question is "how should we conceive and demarcate the empirics of design research". This inquiry will be driven by the aforementioned issues and controversies. In a conceptual inquiry below, these issues will be further explicated and analysed. When studying DR as an empirical practice it is natural to adopt a main focus on activities and outcomes. This means that that clarifying the empirics of DR will imply clarifying outcomes and activities. However, a contextualisation of this focused area (of DR empirics) need to be done. This means that important contextual elements (as e.g. theorizing) related to the focused area also will be studied (at least in parts). DR can be applied to different phenomena in the IS domain. It can be applied to the design of different kinds of models related to IT and IT services. In this paper the focus will be on information systems development (ISD) with intermediary results and an IT artefact as the main end result.

The paper is structured as follows: In the next section the research approach is described. This is followed by an initial analysis and demarcation of empirical work of design research based on a literature analysis. After this, two e-service design cases are presented, which are the empirical bases for the work. The following section is the main part of the paper describing activities, outcomes and other important conceptual distinctions of DR empirics. The paper is ended with conclusions.

Research approach

As described above, the main purpose is conceptual; to contribute to a clarification of DR as an empirical research approach. This research is however also *based on empirical work*. It is not just a conceptual analysis. *Two case studies of e-government design* constitute the main empirical basis for this conceptual development. DR principles have been applied in these two projects. One case is a development of an e-

service and inter-organisational query application in the area of social welfare allowances. Another case is about development of an e-service for requests for changed taxation. Both cases can be seen as combined design research and action research. The action research aspect will not be discussed in this paper. The two research cases had originally other purposes than serving DR conceptualisation (the development of e-government design knowledge), but they have been identified to be generative and useful for the emergence and validation of the presented conceptualisation of DR empirics. For the use in the conceptual development I have relied on the data originally generated in the two cases. The description of each case below contains information about data generation.

This research includes a *conceptual inquiry* concerning unresolved issues in DR. These unresolved issues (see the introduction above and the next section) are, together with observations from the two empirical DR cases, the main input to a conceptual development of DR empirics which is the main result of this research/paper. The results have thus emerged through a multi-grounding approach (Goldkuhl, 2004; Goldkuhl & Lind, 2010; Kuechler & Vaishnavi, 2012). Multi-grounding means the use of three grounding strategies: empirical grounding, theoretical grounding and internal grounding. There have been input from both empirical cases and theory, and the results have been validated in relation to both empirical and theoretical bases. The internal grounding process implies the establishment of a coherent conceptualisation.

Demarcating the empirical work of design research

In the DR literature (Hevner & Chatterjee, 2010; Hevner et al, 2004; March & Smith, 1995) four typical outcomes from design research are described: constructs, models, methods, and instantiations which are all seen as artefacts. Two generic activities within DR are also described: build and evaluate. Artefacts should be built and evaluated. In addition to these activities, two activities are identified in "natural/behavioural science", theorize and justify, which are aimed for the production of theories. Hevner et al (2004) have been reluctant to bring in theories as parts and outcomes from DR in contrast to other scholars (e.g. Walls et al, 1992; Venable, 2006; Gregor & Jones, 2007; Baskerville & Pries-Heje, 2010), who on the contrary claim design theories to be essential results from design research. Theorizing is by Hevner et al (2004) seen as an activity outside of, but related to DR.

This means that it is not actually clear, in the Hevner framework, how DR will contribute to the theoretical development of science. How are the different types of artefacts seen as scientific results vs. practical results? This obscurity has led several scholars to unfold DR in other ways than only build – evaluate. Winter (2008) has made a division into design science ("reflection and guidance of artefact construction and evaluation processes") and design research ("construction and evaluation of specific artefacts"). I find his main labels as inadequate since they are not sufficiently distinguishing. However the distinction is important and promising. Goldkuhl & Lind (2010) have presented a similar distinction: DR consists of meta-design practice vs. design practice. This follows an abstract vs. situational dichotomy in activities and outcomes. Confer also similar divisions of DR into the abstract and the concrete by Purao (2002), Sjöström & Ågerfalk (2009) and Lee et al (2011). It seems now that the reluctance to include theorizing in DR, as it appears in Hevner et al (2004), has softened, and in Hevner & Chatterjee (2010) theorizing and design theory are included as possible elements of DR. Hevner has called this position as "agnostic to the need for design theory" (Gregor & Hevner, 2011 p 4).

Actually, theoretical and empirical work and their interplay are constitutive parts of scientific work. It seems appropriate the describe DR in such terms. Before going into details of demarcating the empirical work of DR, I want to make comparisons with other research approaches. This is done in order to illustrate these two types of essential scientific activities. I have chosen three other types of research approaches for this illustration (table 1). First, I have picked up classical hypothesis testing since this is a common understanding of the interplay between theorizing and empirics. From a DR perspective (the Hevner tradition) this can be said to represent behavioural science which is opposed to DR. This means that scholars following this kind of DR tradition would object that these two approaches are not at all comparable. However, on some abstract level these approaches should be possible to compare. I have also included action research (AR) since there are many scholars (e.g. Sein et al, 2011; Papas et al, 2012) who claim the great resemblance between DR and AR. Action research should hence be seen as a comparable research approach. I have also included a fourth research approach in this comparison: The grounded

theory (GT) approach (e.g. Corbin & Strauss, 2008). This is done in order to give a richer view of the interplay between theorizing and empirics. There are clear contrasts between a qualitative approach like GT and a classical hypothesis testing approach (including determinations of measurement scales and samples in advance). The theoretical-empirical interplay in research can be described in a sequence of three stages: 1) initial elements of theorizing, 2) generation of empirical data and 3) final elements of theorizing. This kind of three-stage sequence is very clear in classical hypothesis testing. In the three other research approaches there is more of a continual back-and-forth movement between theoretical and empirical work. The main idea of the comparison is, however, not to show this continual interplay, but rather what theoretical elements that precede respectively follow from empirical work and also how to conceive the kind of empirical data in the different research approaches. This comparison forms a background and justification for the characterization of DR empirics in the following.

Table 1. Interplay between theorizing and empirics in different research approaches

	Classical hypothesis testing	**Grounded theory approach**	**Action research**	**Design research**
Initial elements of theorizing	Hypotheses (generated from knowledge gaps in extant theories)	Research idea	Research idea; and possibly existing theories with relevance for change process	Research/design idea; and possibly existing theories with relevance for design process
Empirical data	Collected data according to defined measurements and sample	Generated rich data following unobtrusive procedures	Data concerning change process, results and effects	Data concerning design process, generated artefacts and their uses
Final elements of theorizing	Corroborated or falsified hypotheses	Categories leading to grounded theory	Abstractions concerning change process, results and/or effects	Abstract design knowledge (design guidelines, design theories)

It has been possible to describe these four research approaches according to the three-stage scheme. It is possible to distinguish between initial and final theorizing elements in all four approaches. It is also possible to identify and demarcate the character of empirical data in the research approaches. Some comments can be made: In classical hypothesis testing, empirical data is collected according to pre-stated procedures and questions. In all other approaches, there is a continual emergence of data capture. It is not that data are just *collected*. There is a *generation* of data where the researchers play an important role. It is also important to note that in AR and DR (and probably sometimes in GT also), there is a generation of researcher-influenced data. Both in AR and DR, the purpose is to try out some change/design ideas and asses effects of these ideas.

As a consequence of this analysis, design research is divided into one *abstract* and *theorizing part* and one *empirical* and *situational part* where concrete artefacts are designed (figure 1). To further the analysis of DR empirics it is appropriate to look into the four kinds of artefacts from March & Smith (1995) and Hevner et al (2004). Goldkuhl & Lind (2010) have conducted an analysis of these four artefact types and classified them according to an abstract – situational dichotomy. They characterize constructs and methods as abstract outcomes. Constructs are defined as "concepts" and "conceptualizations" (March & Smith, 1995 p 256) and as "vocabulary and symbols" (Hevner et al, 2004 p 77). A method is defined as "a set of steps (an algorithm or guideline) to perform a task" (March & Smith, 1995 p 257) and is exemplified with systems development methods as a typical example. Goldkuhl & Lind (2010) characterize models and instantiations as situational. This characterization is based on how models are presented by Hevner et al (2004 p 78-79): "Models aid problem and solution understanding and frequently represent the connection between problem and solution components enabling exploration of the effects of design decisions and changes in the real world." Models are thus seen as artefacts that are used in the design process of IT artefacts. Hevner et al (2004) describe an instantiation as a prototype or a specific working system or some kind of tool. This makes it typically a situational artefact.

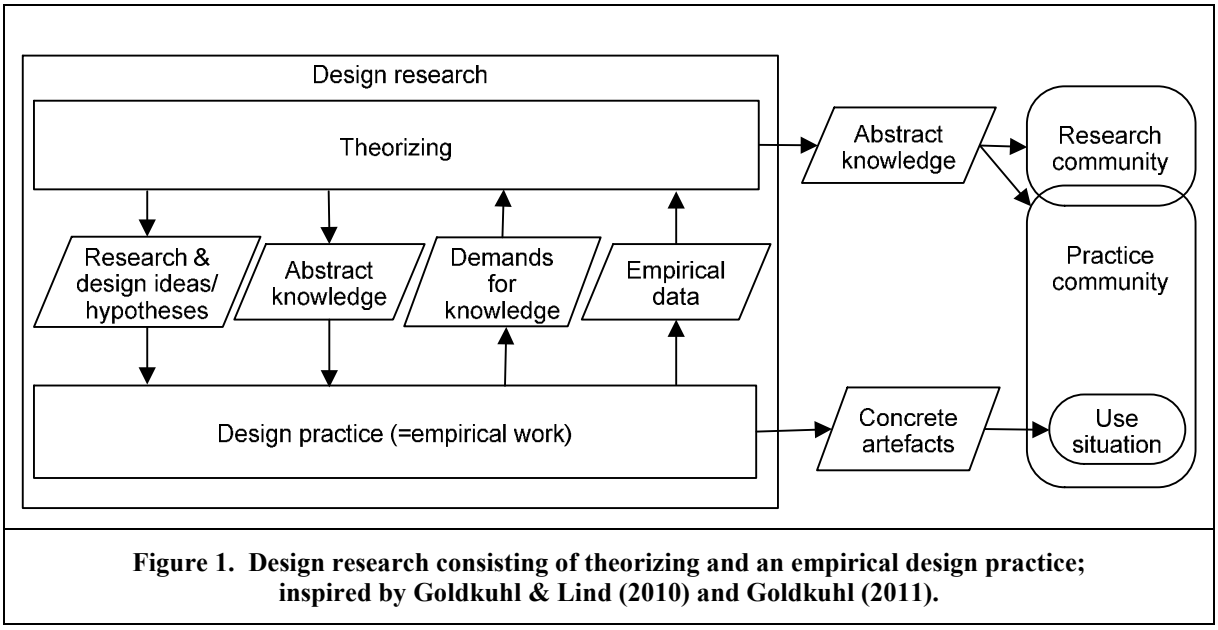

Figure 1. Design research consisting of theorizing and an empirical design practice; inspired by Goldkuhl & Lind (2010) and Goldkuhl (2011).

Hevner et al (2004) and other DR scholars (e.g. Iivari, 2007) have tried to postulate the scientific character of the design process in DR. They search for criteria that the design of artefacts can be seen as scientific. They claim that artefacts must be novel and innovative. Other arguments are that the design process should be theory-informed. Iivari (2007) requests the design process to be as transparent as possible in order to be design science. I claim that these searches for "science" in artefact design are partly misled. It is not necessary that that the design process lead to totally novel artefacts. As researchers, we embark on artefact design in order to study design process and design products. The design process, and its outcomes, is an *empirical part* of our research work (table 1 and figure 1). As stated above, science evolves through cycles of theorizing and empirical investigations. Design practice is empirical work and what comes out from this work is empirical data. *All concrete artefacts that are produced are examples of empirical data*. This means that the ISD artefacts in DR are multi-functional. They have distinct roles in the design process leading to designed artefact to be used. The ISD artefacts, in DR, have also roles to be empirical data as basis for testing and theorizing in research.

Empirical work in research can be experimental and explorative. Researchers arrange situations, based on ideas and hypotheses, in order to test and learn. Trying out things can include the building of (new) artefacts. Scientific results in social and natural science are made in abstract and generalized forms. Observations, examples etc are all empirical data which are used as a basis for theorizing. Empirical data can be used to generate hypotheses and theories and to test hypotheses and theories. Data (like observations, situational artefacts) are means for developing scientific results (like constructs, theories and frameworks). Empirical data are always instrumental in relation to *scientific end results*. Empirical data are *intermediary research results* generated by researchers in order to produce abstract knowledge.

What is needed for a design practice to be part of design research is that *empirical data are generated in a proper way and used for theorizing*. This is the key criterion for a process of designing artefacts to be scientific. Both building and evaluating (as necessary activities in the design process) generate valuable data. Novelty, theory-use and transparency may be desirable elements of the design process, but they are not necessary ingredients in order to make it a part of a scientific process. Hevner & Chatterjee (2010 p 3) state that "research requires collection and interpretation of data or creation of artifacts". I claim that the little word "or" is erroneous here. It is not the case that we either produce data or artefacts in design research. We produce artefacts since they are the *key empirical data* for our theorizing in design research.

As said above, there are controversies concerning the production of design theories as results of DR. There does not either seem to be a consensus about the use of theories in DR (Gregor & Hevner, 2011).

Sein et al (2011) has formulated a principle for DR on the "theory-ingrained artifact", which means that the design of an artefact should be based on explicit theories. In this paper the broad notion of abstract design knowledge is used to cover constructs, theories, design principles, methods and abstract models (Goldkuhl & Lind, 2010). Abstract design knowledge is seen as a research end results from DR. However, abstract knowledge should also inform the design process. Such furnishing of abstract knowledge should be seen as responses to knowledge needs in the design process (figure 1). For greater details concerning the interplay between theorizing and design practice see Goldkuhl (2013).

Two design research cases

Two design research cases have played a crucial role for the conceptual development presented in this paper. These two cases are briefly described below. They are two cases of e-government design, with special emphasis on public e-services. Much literature on public e-services has a rather limited view with a focus on the e-service artefact and its use by a citizen, e.g. Buckley (2003). In these cases, we took a broader process-oriented approach when designing public e-services. The research described below has been conducted based on ideas and hypotheses that process redesign should play an important role in e-service design (e.g. Daniel & Ward, 2006). The cases are also based on the idea of policy and value realization in e-government design (e.g. Flak et al, 2009; Rose & Persson, 2012).

An e-service for social welfare allowances

This case study is from a project in the social welfare sector. Two researchers (one of them the author) have participated in this project as action researchers and design researchers. The case has been more thoroughly described in Goldkuhl (2012) and Eriksson & Goldkuhl (2013). These descriptions include also how AR and DR have been integrated in this case. Several municipalities participated in the project in order to develop joint IT solutions. These solutions comprise both an e-service application for clients and a multi-query application for collecting information about clients from state agencies. One impetus for starting the project was a new regulation that gives the municipalities better possibilities to obtain information about clients. The handling of client information within the public sector is severely restricted due to data protection regulations. The new regulation made it easier for municipalities to electronically obtain information about the clients' economic situation. Information can now, on demand, be transferred electronically and immediately from state agencies (like the Social Insurance Agency and the Board for Study Support) to the social welfare offices at the municipalities.

The IT development was conducted through two phases. First the multi-query application was developed and launched to the participating municipalities. Now queries concerning the clients are made by the social welfare officers through the multi-query application and answers will be obtained immediately and exposed to the officers. This communication was earlier mainly conducted through telephone calls and a slow batch query application. After successful implementation of this IT artefact, the project continued in the second phase to develop an e-service artefact.

Process modelling played an important part in the design of the e-service. A new process design was made comprising both a new e-service and the newly implemented multi-query application. The process modelling was conducted through modelling workshops with the project team (domain experts from the municipalities). The author/researcher led these modelling workshops as an active facilitator (cf. e.g. Macaulay, 1999). The models were detailed enough (visualizing the process) to ensure an informed consensus in the team and a good basis for designing the e-service artefact. The process modelling was followed by user-interface design and prototyping also conducted iteratively in design workshops. Process models and user-interface prototypes were continually developed and evaluated by the project team during these workshops. In order to obtain accurate data from the design workshops, these sessions were audio-recorded. Several versions of the IT artefacts have been put into use. After the implementations of the IT artefacts, data were collected from users concerning their experiences and opinions from use.

A taxation e-service

This case study is from a project working with a taxation e-service. Two researchers (one of them the author) have participated in this project as action researchers and design researchers. The project worked with development of an e-service for the business sector concerning requests for a changed taxation. Every company has a decided taxation level based on earlier figures. The company pays taxes during the year according to this settled taxation level. A company can request a changed taxation due to changed circumstances. This request will be handled by the Tax Agency and a decision will be made about a changed or retained taxation level. These requests were earlier submitted only on paper forms. The IT development comprised development of two channels for request submission: 1) a continued paper based service, but internally at the Tax Agency changed to scanning of forms direct into the case handling IT systems, 2) a new e-service where requests can be submitted electronically for seamless transfer to the case handling IT systems. Process models were built in close cooperation between the researchers and the domain experts. The paper forms for the taxation request were fairly complex to fill out and the design goals were to create an e-service that gave substantial support to user. Easy-to-read information about tax rules, guides to select the appropriate e-request, earlier registered figures and procedures for tax calculations were included in the e-service in order to reduce complexity and increase service. User-interface design through prototyping played a pivotal role in the design work. Modelling and prototyping were conducted in design workshops and in individual work. The researchers acted as a facilitators and lead-designers in the e-service design. Two types of prototypes were generated during the design process. First, sketches of user-interface screens (lo-fi prototypes) were produced by the researchers and further developed together with the domain experts in the design workshops. Later, a consultant created clickable prototypes (hi-fi prototypes) in a high-level software tool in order to further demonstrate the e-service before the final construction.

Design workshops have been audio-recorded and field notes have been taken. The role of process modelling in the e-service design process has been investigated through a simple questionnaire to the participants.

Design as cycles of propose, visualize and assess

There are some important observations from the two cases that need to be brought up as a basis for the further conceptual analysis. These observations and reflections are concerned with clarifying the constituents of the design process. What is observed concerning the design process is not to be considered as unique traits of these two design cases. What has been observed should be seen as generic steps in a deliberate design process, although these steps are not often explicitly accounted for in general descriptions. The two design processes has applied an *ideal of deliberate design* with explicating design alternatives and with explicit discussions and assessments of such design proposals (MacLean et al, 1989). These observations are based on in-depth studies of what people do during design process of ISD. Different micro-actions are typified and ordered into patterns. A generic basic pattern is described here that apply to both modelling and prototyping. These two concepts (and their relations) will be further discussed below in the following sections. A generic recursive construct of proposing (P), visualizing (V) and assessing (A) activities is considered to be the essence of design in ISD (figure 2). The conceptualisation of design cycles is based on work performed in design workshops (in the two cases) where designers and domain experts were present and participated more or less active in the design processes. The design workshops consisted of active participation around modelling and prototyping. People have discussed design options; models and prototypes have been created, shown and inspected.

The creation of a solution model in ISD is always preceded by some identification of a design alternative. Someone, the active modeller, or someone else in the design team, *proposes* some solution idea. This expressed idea can be *visualized* in a model and assessed by the participants. As a result, they can be content with the proposal and how it is described in the model and then continue with other design issues. This means that the model is *validated* at this moment. However, there might instead be objections to the proposed and visualized design solution. This can lead to the formulation of new design proposals and a new design cycle starts concerning this design issue. This generic construct of P→V→A is important for the further conceptual analysis. There are, however, alternatives (or variations) to this construct. There might be a construct like P→A, where an expressed design proposal is rejected immediately after it has

been formulated, which means that it is never visualized in a model. An expressed proposal can also be assessed and modified before it enters into a model, which means a construct like P→A→V→A. Design is thus considered to be seen as proposing a design solution (P), which is assessed and validated (A) through the use of visualization in models (V). What has been here said above about modelling is also valid concerning prototyping. The creation and use of prototypes seem to follow the same type of fundamental design cycle (P→V→A).

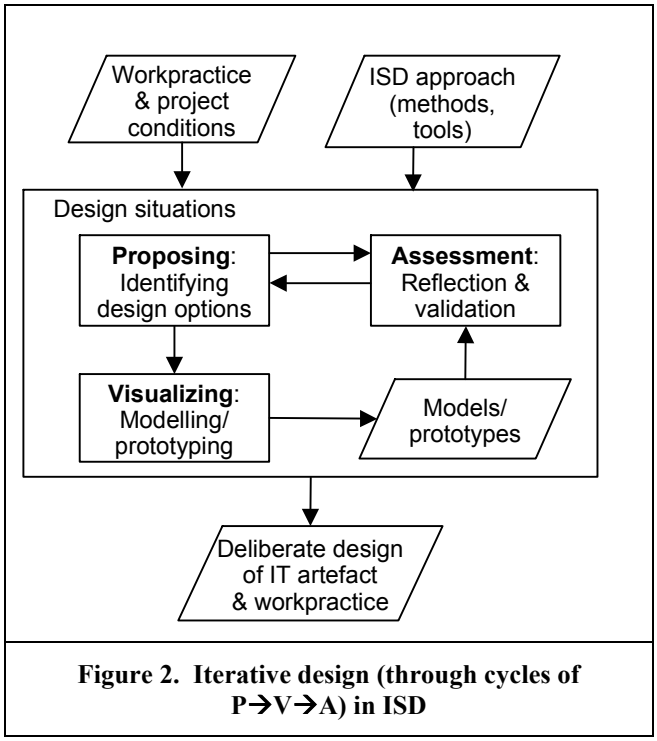

Figure 2. Iterative design (through cycles of P→V→A) in ISD

The iterations of modelling and prototyping should contribute to *design consideration*. The result of this modelling process should be an *informed and deliberate design* of IT artefacts and workpractices in an integrated manner. Figure 2 conceptualises the iterative process around modelling/prototyping. There are 1) activities of identifying and formulating design options ("proposing"), 2) where these options then are illustrated through model/prototype building ("visualizing") and the generated models/prototypes 3) give rise to reflection and validation ("assessment"). This assessment can lead to further iterations of proposing, visualizing and assessment.

Conceptualising the empirics of design research

Situational artefacts: Symbolic models, prototypes and products

ISD consists of many different activities and resulting outcomes. The produced results are situational artefacts according to the conceptualisation described above. What kind of artefacts can be distinguished in ISD? The four types of artefacts from the Hevner framework have been differentiated into abstract and situational results by Goldkuhl & Lind (2010) as described above. Models and instantiations are considered to be the main situational artefacts. This division needs to be brought further and clarified. An instantiation is defined as an implemented system or a prototype (Hevner et al, 2004 p 77). A prototype is a step towards an implemented working system in a similar way as a model is. We can thus identify *models* and *prototypes* as *intermediary* results and the implemented system as the *end* result of an ISD process. I here call the end result of ISD (i.e. the produced IT artefact) for a *product*.

The relations between models and prototypes need, however, to be further elaborated. What is meant by model, and what is meant by prototype? Actually, a prototype is considered to be a kind of model (Naumann & Jenkins, 1982). It is a special kind of representation of future system. It is created to visually *resemble* the coming system. A prototype has thus other traits than "normal" models of ISD. Such models (like e.g. process models, information models) are not directly visualizing the IT artefact. Linguistic constructs are used to *symbolize* the coming IT artefact and the changed workpractice. It should hence be possible to distinguish between symbolic models and prototypes as a special kind of a resembling model.

Prototyping can, however, be done in different ways and can have different functions in the development process. There is often a distinction made between lo-fi and hi-fi prototypes (e.g. Walker et al, 2002). In the taxation case above, we used these two different types of prototypes. Lo-fi prototypes can be seen to be a kind of simple *iconic* model of a proposed IT artefact. A typical example is a drawn sketch of a user interface screen. Hi-fi prototypes use software tools and they are often executable (or at least clickable). Such prototypes resemble the final system more fully and the creation of them involves usually some software generation. An important distinction between lo-fi and hi-fi prototypes is that lo-fi prototypes are "passive" models while hi-fi prototypes are dynamic models with the purpose to expose some kind of behaviour of the future system.

To clarify the differences between these different types of models (and prototypes), I will use a classification from learning theory with three kinds of representations: enactive, iconic and symbolic representations (Bruner, 1964). The hi-fi prototypes can be seen to have an enactive (and iconic) representation. It is enactive since it has a capacity of exhibiting some behaviour of the system. A lo-fi prototype does not have a dynamic capacity of that kind. It is a typical iconic model, since it based on a direct resemblance with parts of the future system. Other types of models, like process models and information models, are typical examples of symbolic models while using abstract linguistic constructs for describing the system and its environment. Symbolic models can be divided into as-is models and to-be models. An as-is model is used to describe and evaluate a current situation; often made in an initial step of ISD. A to-be model is produced as a description and proposal of a future state (a future product and its possible uses). The different kinds of artefacts generated through ISD are described in table 2.

Table 2. Different types of situational artefacts in ISD/DR

Type of artefact	**Character**	**Purpose**	**Producing activity**
Symbolic model (as-is)	Symbolic representation	Describing a current situation	Diagnosis-modelling
Symbolic model (to-be)	Symbolic representation	Proposing & symbolising a future situation including a product and its usage	Designing through symbolic modelling
Lo-fi prototype	Iconic representation	Proposing & illustrating a future product through resembling sketches (look-alike)	Iconic prototyping (designing through simple example)
Hi-fi prototype	Enactive representation (materialised in some way)	Demonstrating a possible future product through enactive instruments (behave-alike)	Enactive prototyping (designing through advanced example)
Product	Materialised as a usable product	Intended for practical use in operational practices	Construction (realising design)

There is a terminological challenge in discussing modelling and prototyping in ISD. As said above, prototyping can be seen to be special kind of modelling; the creation of iconic and enactive models. However, when discussing *modelling* in ISD, symbolic modelling is usually meant. I will therefore (in text and figures below) often use the compound wording modelling/prototyping in order to explicitly cover the three kinds of identified models.

Modelling is a central part of a design process. In the general design literature (e.g. Cross, 2007; Lawson, 2004), sketches and drawings are considered as major means in the design process. People design through models. Models are bases for constructing and realising products; models are transformed into products. As described above, different types of models can be used during design: symbolic, iconic and enactive models; see table 2. This typology is based on insights from the two cases (thus empirically grounded) and from theories in design, learning and information systems development (thus theoretically grounded).

Activities, outcomes and other data

Models including prototypes are important outcomes of an ISD process. They are not seen as the primary end result of the ISD process (although they can be part of an ISD documentation). They are intermediary results to be used as a basis for the construction of the intended IT artefact. In order to understand the usefulness of symbolic models it should be valuable to study the subsequent artefacts (prototypes, products) of the ISD process. For example how different parts of the symbolic models are transformed into features of the prototypes and products. The same type of reasoning applies to the relations between prototypes and products. For a design researcher it is important to trace the properties of the IT artefact to descriptions made in symbolic models and prototypes.

From the differentiation of artefact types in ISD (table 2), it follows that different types of activities can be identified: diagnosis-modelling (i.e. generation of as-is models), design-modelling (symbolic modelling, iconic prototyping, enactive prototyping) and construction. A contextual description of activities and outcomes from the design practice is shown in figure 3. Relations to the local operational use practice are included in this description. Iterations within modelling/prototyping are described, but iterations from construction are left out in this description. As shown in this figure there are four outcomes from the design practice: Symbolic models (both as-is and to-be), iconic prototypes (lo-fi), enactive prototypes (hi-fi) and constructed IT artefacts (products).

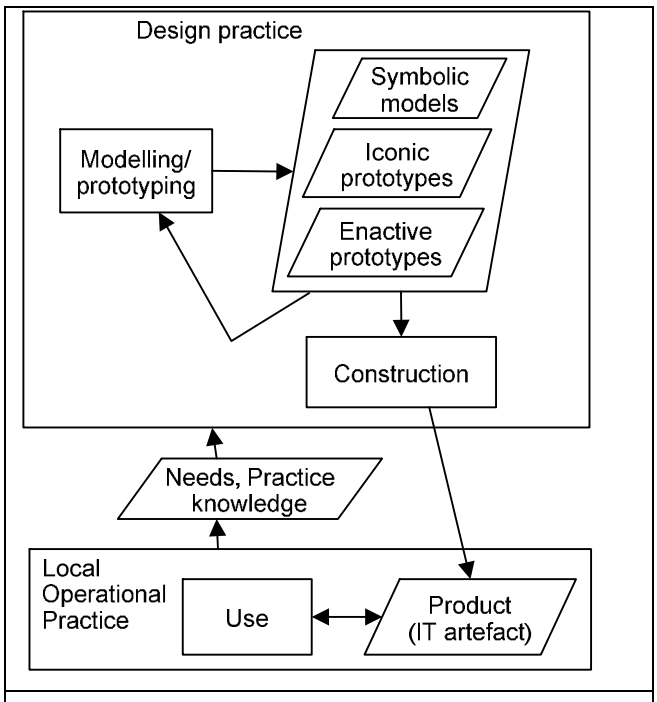

Figure 3. Different activities and outcomes from a design practice (within empirical part of DR)

Modelling and prototyping proceed through propose, visualize and assess cycles. This iterative nature of design work can give rise to many versions of models and prototypes. The different versions and their

evolution are important parts to study for a design researcher. This means that the models and prototypes are very important empirical data from the ISD practice to be used in the theorizing part of design research; see below.

A design practice contains in itself data collection. There is a need for data about the workpractice, possibly other similar workpractices, existing IT artefacts of similar kinds, and different informational and technological options. These data are needed in order to generate informed design alternatives and to make deliberate design decisions.

In the design/visualizing practice there is hence a need for data collection in order to build models and prototypes. An as-is model should be a proper and clarifying description of the current situation. In order to make such a model, the inquirers need to gather data about the current workpractice. Data can for example be interviews, observations, documents, artefact inspections, discussions during modelling workshops. Data collection may also be needed for generation of to-be models including prototypes. This kind of data gathering is made for the sake of building models/prototypes. There is a clear practical intent of this data collection. In figure 4 this is called "*embedded data collection*". This data collection is an integrated and supportive part of the design process. It is driven by a *design interest*. Even if this kind of data is generated with the primary purpose of being a basis for practical design, it may be used for theorizing purposes as well. As a *by-product* of the design process, this kind of data can be fed into the theorizing process together with the produced artefacts (see figure 4).

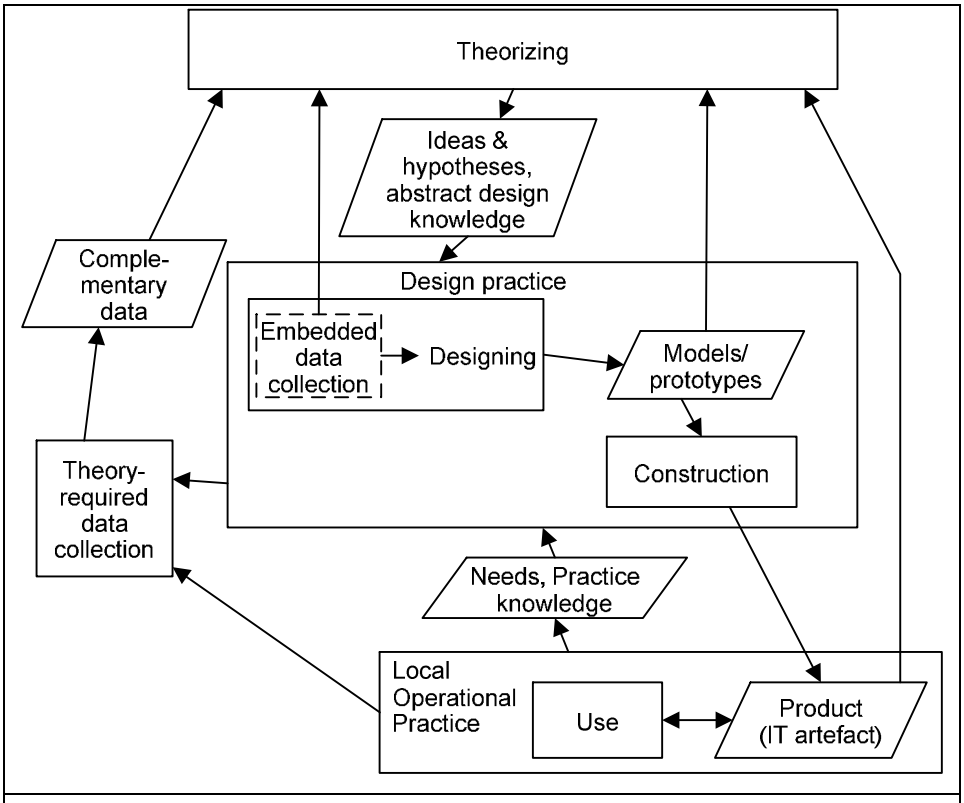

Figure 4. A contextual view on design research in ISD: interaction between theorizing and design practice

Even if data - as artefacts and other supportive data - are generated (as by-products) in the ISD design practice, there may of course be a need for other kinds of data as a basis for theorizing. In figure 4 this is called "*theory-required data collection*" and is seen as a complementary data collection activity. This kind of data is *not* generated for the sake of the practical design work. These data are not used in the design process. They are generated *exclusively for the sake of theorizing*. This kind of data can have an origin from studies of the design practice and also from studies of the use practice (local operational practice).

This kind of data collection can be done in design sessions (like audio/video recordings, taking field notes) or outside these (e.g. interviews or questionnaires). Such data collection is driven by *research interest*. It may be fairly open in its generation, e.g. audio/video recording of design sessions, or it can be directed by specific questions based on a more focused research interest (e.g. certain hypotheses).

Three kinds of evaluation in design research

Evaluation is seen as a fundamental activity in design research. According to March & Smith (1995) and Hevner et al (2004), DR is constituted by the build – evaluate cycle. It is stated that "the utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods" (Hevner et al 2004 p 85). Evaluation is considered as both an iterative correction mechanism in design and a summative assessment of how well the designed artefact meets requirements. Venable et al (2012) discuss timing and setting of evaluation. They distinguish between ex ante and ex post evaluation and between artificial and natural settings. Sein et al (2011) contest an explicit differentiation between building and evaluation and they argue for an integrated mode of evaluation: "evaluation is not a separate stage of the research process that follows building … instead, decisions about designing, shaping, and reshaping the ensemble artifact and intervening in organizational work practices should be interwoven with ongoing evaluation" (ibid p 43). Their view on evaluation as a "concurrent" activity seems to be in line with the observations and analyses above about embedded evaluation (called "assessment"); see figure 2. There are however other needs for evaluation from both design and theorizing perspectives. The embedded evaluation is done with models and prototypes as the evaluation objects (i.e. an anticipated product). It is a natural design setting, but is *not* a natural *use* setting since it does not yet exist. For a proper design there may be needs for evaluation in real or close-to-real use settings through the use of products or realistic prototypes. Such evaluations are used in the sake of testing and possibly improving the design. It is a typical formative evaluation; see figure 5.

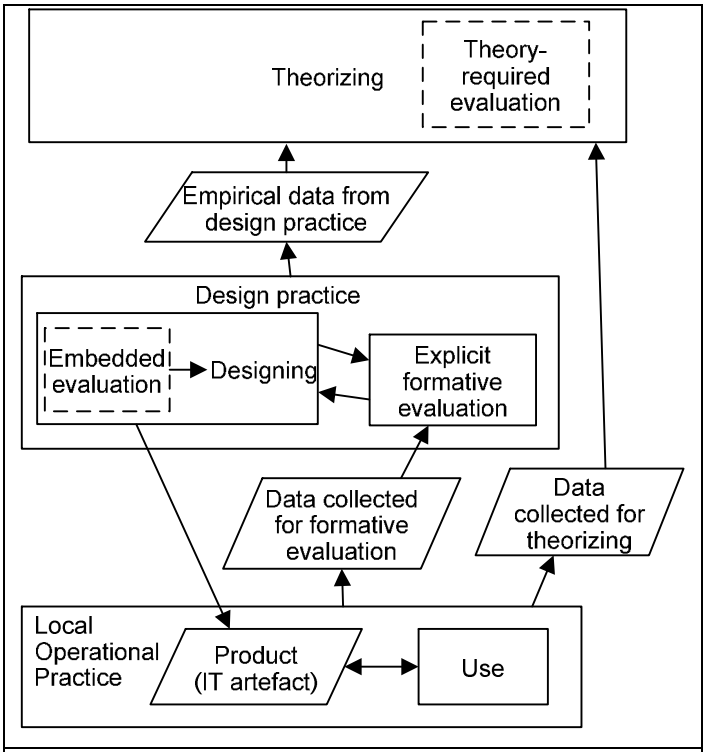

Figure 5. Three kinds of evaluation in design research

Embedded evaluation of models/prototypes and explicit evaluation of products/prototypes are both formative evaluations aiming to improve the design from stakeholders' perspectives. As such these

evaluations belong to the design practice and they are empirical activities from a research perspective. The researchers might, however, need evaluations that go beyond such design-supportive evaluations. Certain design ideas, which have inspired the artefact design, may need to be studied more carefully. More empirical validation may be needed than the type of validation that is requested from practitioners' viewpoints. Different kinds of data (both theory-required data and data as by-products) can be used as bases in this evaluation process. This kind of evaluation is seen as part of the theorizing process.

The analysis conducted here reveals thus three types of evaluation in design research (figure 5): 1) embedded evaluation in design activities, 2) explicit formative evaluation with data from use settings and 3) theory-required evaluation in order to assure theoretical validity of results.

Theorizing as a support activity to design practice

Theorizing creates abstract knowledge aimed for research and practice communities as can be seen from figure 1. The theorizing practice uses empirical data from the ISD design practice and from the complementary data collection as input for abstraction, reflection, evaluation and theory building. However, theorizing produces also outcomes for the design practice. There is a dialectical relation between design practice and theorizing (Goldkuhl & Lind, 2010; Goldkuhl, 2013). Theorizing is thus to be seen partly as a *supportive knowledge practice* to the design process in design research. DR wants to stretch design practice in a pragmatist vein, and in order to do this, useful theoretical knowledge is furnished into the design work (Goldkuhl, 2011). In figure 4 this is described as "abstract design knowledge". This follows the ideals of the "theory-ingrained artifact" formulated by Sein et al (2011).

There may be some initial *research* or *design ideas* that the researchers want to test through the design work. These ideas/hypotheses will play an important role for directing the design and also for the theory-required data collection. There is a continual interaction between theorizing and design practice. Experiences from the design can give rise to new or refined ideas/hypotheses. New and modified ideas/hypotheses can be furnished back into design work.

The design practice may be governed by different kinds of abstract design knowledge that is considered useful in the design process (Goldkuhl & Lind, 2010). This abstract design knowledge can consist of design theories, generic models, ISD methods or other types of design guidelines/principles. The theorizing sub-practice of design research is where deliberations is made of what kind of abstract design knowledge should be furnished to the design practice, partly based on research interest and partly based on knowledge needs from the design practice.

The theorizing practice may comprise a continual reflection and evaluation of the design process. Abstractions may be done concerning the ongoing design practice and/or the local operational practice and these *emergent abstractions* can be fed back into the design process. As said above, it is important to acknowledge that evaluation activities are performed both in theorizing and in design practice. In design practice, formative evaluations are performed with the purpose to gradually improve the situational artefacts. Evaluation in theorizing has the purpose of improving produced abstract results (as theories and methods).

The empirics of the two design case studies

It is time to return to the two design cases in order to review the different conceptual distinctions introduced above. The purpose of this is to demonstrate that the conceptual distinctions described above are well grounded in the cases, as an empirical validation.

The design processes have generated several kinds of results; both intermediary results as symbolic models (process models and information models), prototypes (screen visualizations) and end results as IT artefacts for use. There are also many examples of embedded data collection. Different participants have generated different kinds of memos and investigations as bases for design. There have been studies of current paper forms, written regulations, and usability and language policies. There exist also e-mail communication between participants with comments on certain proposals and new suggestions. These different documents and the memos and also more informal comments on these documents and models

are typical examples of collected data for the sake of design. All these data played important roles in the design process. These data were also a god basis for the researchers' theorizing work.

Many design meetings have been audio-recorded. Usually two researchers have participated in the meetings, which has facilitated the generation of documentation in field notes. The main reason for this data collection has been to obtain a proper empirical material as a basis for theorizing, for example concerning the application of design principles, which will be described below.

After deployment of the multi-query artefact (in the social welfare case), the researchers have collected empirical data concerning its use (interviews of case handlers and some quantitative data). This data collection was part of a separate evaluation informing the redesign of the multi-query artefact. Outside the design endeavour, the researchers have also collected data (through interviews) about motives for the municipalities to join the project. This has been done for certain theorizing purposes.

In both cases there has been a continual interaction between design and theoretical reflection. Emergent design principles have been furnished adapted to this design situation. Theorizing has also produced abstract knowledge aiming for researcher and practitioner audiences.

One purpose of researcher participation in the two cases was a desire to apply and test a method for e-service design (Goldkuhl & Röstlinger, 2010). This method had emerged through several earlier DR cases on e-service design. This method was a reflected integration of different aspects of e-service design: process modelling, regulative analysis, analysis of workpractice language/conceptual modelling, user interface design and architectural IT design. This method was applied (as abstract design knowledge) in the two design cases. The researchers used different method components in the design work. Several usability design principles had emerged through earlier e-service design cases and these were applied in the two cases. Some of these design principles was sharpened during design and still some principles emerged during the case studies. It is beyond the scope of this paper to go through these design principles. They are just briefly mentioned here for the sake of exemplifying. The following usability design principles were applied and studied during the e-service design cases: Performative transparency, conceptual clarity, legal transparency, consequential transparency, context-based knowledge support and minimal registration demands. The resulting IT artefacts carry several of these design principles and can therefore be seen as theory-ingrained artefacts (Sein et al, 2011).

There was thus an initial set of design principles (from prior research), which have been applied and tested through concrete design processes. These design principles have been continually refined during the design work. Different reactions from the participants concerning these principles have been recorded as empirical data for further reflection by the researchers. All versions of models, prototypes and tested IT systems have also been important empirical data for further theorizing. The results from these DR cases are twofold: 1) from design work: IT artefacts with certain properties concerning usability (i.e. manifestations of design principles) and 2) from theorizing: refined design principles (as abstract design knowledge) that have been empirically grounded through design. The produced IT artefacts are most essential empirical data that are used for articulation of the theorizing results (the design principles).

Conclusions

This paper has been an investigation into the empirics of design research. It has contributed with a conceptual clarification of DR as an empirical research approach within IS. It is a response to the conceptual obscurities and controversies mentioned in the introduction of this paper. It will not resolve all pending issues, but it has contributed with several important conceptual clarifications that will be summarized below.

Design research is divided into

- Theorizing producing abstract knowledge
- Design practice which is empirical work from a research perspective

The design practice generates different situational artefacts. In ISD the main *situational artefacts* are:

- Symbolic models

- Prototypes (iconic and enactive models)
- Products (IT artefacts for use)

The design practice of DR produces *empirical data as by-products* of the process:

- The generated artefacts (models/prototypes, products)
- Data as input to design (from embedded data collection)
- Explicit formative evaluations

Data are also *generated* in the empirical part of design research *exclusively for theorizing purposes*:

- Separately collected data (theory-required data collection)

The *design process* that creates different kinds of data can in its essence be described as a cycle of three types of *generic actions*:

- Propose
- Visualize
- Assess

Evaluation is intrinsic to design research. Three kinds of evaluation have been distinguished:

- Embedded evaluation in design activities ("assess")
- Explicit formative evaluation with data from use settings
- Theory-required evaluation in order to assure theoretical validity of results

The first two evaluation activities belong to the empirical domain. The last one is considered as a part of theorizing, but uses data from the empirical activities.

The creation of artefacts and other data through the design process are *multi-functional*. 1) These creations have a design purpose of arriving at useful IT artefacts in practical settings. 2) They are also empirical data to be used in theorizing for the production of theories, design principles and other types of abstract design knowledge as end results from design research.

The research contributions of this paper have been generated through a combined approach of empirical design research and conceptual inquiry. These conceptual clarifications can guide future design research and thus generate more corroboration and further refinements and conceptual nuances.

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