2011

Strategies for Creating, Generalising and Transferring Design Science Knowledge – A Methodological Discussion and Case Analysis

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ABSTRACT

Design Science Research has been well accepted as part of Information Systems Research. The discussion about the research process and the structure of design theories has been going on for some time. While research has been done on the relation between design theories and other types of theories, not much has been said about how design knowledge can be re-used. Other disciplines refer to such re-use as "generalisation" and "transfer". We define a three-level separation of design abstraction (short-, mid-, and long-range) and show how knowledge re-use strategies operate between and within them, as well as how they relate to generalisation and transfer. Each strategy is supported by a case from an existing publication, showing that the types of design theories and the research strategies can be found in practice. We argue that these research strategies can provide guidelines to researchers and reviewers for planning, performing and evaluation Design Science Research.

Keywords

Design science research, knowledge creation, knowledge transfer, generalisation, research strategies.

1. INTRODUCTION

Design Science Research (DSR) is a recent mode of research in Information System Research (ISR). It is distinct from natural science, as it is concerned with the creation of artefacts relevant to practitioners, whereas natural science is "aimed at understanding reality" [18]. A sizeable amount of research has been done in recent years to outline and detail the methodological principles of design science in ISR. Papers on DSR, such as the seminal paper by Hevner et al. [13], have been published in prestigious journals, illustrating the increasing acceptance of DSR as a valid research paradigm within the community [10; 15; 23; 29; 30].

10th International Conference on Wirtschaftsinformatik,
16th - 18th February 2011, Zurich, Switzerland

As in any other scientific discipline, Information System Research aims at developing knowledge based on evidence. A desired attribute of such knowledge (usually represented by theories in the natural science paradigm) is generalisability. This means that a theory is valid "[...] in a setting different from the one where it was empirically tested and confirmed." [16]. But even within the natural science paradigm the achievability of generalisation is debated, especially with regard to qualitative research methods [11; 16]. Here, the concept of transferability is introduced [11] to contrast generalisability. Settings might be similar, especially when research involves social dimensions, and insights might be transferred from one to the other but still be far from (statistical) generalisability.

The discussion about creation of design knowledge has so far either focussed on the construction (and sometimes evaluation) of a single design theory or the discussion on how design science as a field is connected with other parts of ISR [13]. The publications of design theory structures acknowledge the use of theories and other types of knowledge [10; 32], but do not explicitly examine the relation to other design theories. From our own design experience and knowledge of design examples, it appeared unintuitive that designs should be that "monadic", also considering that other fields practice knowledge re-use and other strains of design discuss the matter [4].

The aim of this paper is to identify re-use and creation strategies of design knowledge. Studying similar discussion outside of DSR, we saw that "generalisability" suggests different levels of knowledge and "transferability" abstraction (at least in some sources) and describe a lateral movement between settings. We adopted this for designs by introducing three levels of abstraction, in which short-range designs refer to individual solutions, mid-range designs refer to the notion of design theories and long-range designs refer to "schools of thought" and paradigms. Furthermore we employed the "purpose and scope" concept of [10] to distinguish if designs addressed a similar or different problem. We identified knowledge creation and re-use strategies on this basis as transformations of design knowledge that occur between or within abstraction levels and purpose and scope. For each strategy we present a published example to show how the strategy looks like in practice.

The remainder of this paper is organised as follows: first, we introduce the concepts of generalisability and transferability form behavioural Information Systems Research. Then, we introduce Design Science Research with its different types of output. Based on the types of design identified, we present strategies to create, generalise and transfer knowledge. For each strategy, we present an ISR publication where the strategy has been realised. Finally, we discuss the approach and draw a conclusion.

2. KNOWLEDGE CREATION IN INFORMATION SYSTEMS RESEARCH

To understand the knowledge creation process in Information System Research, it is helpful to understand what knowledge is typically created trough research in this discipline. The Merriam Webster dictionary defines knowledge as "the fact or condition of knowing something with familiarity gained through experience or association" [19]. Scientific knowledge, then, is a subset of this knowledge; namely the knowledge that has been gathered through following scientific methods. While different types of knowledge might exist (Hevner et al. [13] list theories, frameworks, instruments, constructs amongst others), theories are at the core of this knowledge, as the behavioural side of IS research is focussed on "the development and justification of theories" [13].

Theories, as all scientific knowledge, are supposed to be supported by evidence. Usually, though, the theories make claims about a range of settings or phenomena that are larger than the instances in which the theory has been tested. It is not possible to test instances that do not exist at a given point in time and for practical reasons it might not be possible to ever test every possible instance. This very circumstance is what makes theories and scientific knowledge in general valuable: Being able to reason about a phenomenon that is new, or has not been tested yet, based on prior experiences. "Academic knowledge involves the quest for general or 'covering' laws and principles concerning the fundamental nature of things. The more context free, the more general and the stronger the theory." [1].

2.1 Generalisability

The activity that gives knowledge a wider use is called "generalise" as in "give wider use to something: to use something in a wider or different range of circumstances, or be used in this way" (Encarta World English Dictionary). "Generalisability is a major concern to those who do, and use, research." [16]. As a body of knowledge should contain knowledge useful to the whole discipline, generalising is an important research activity.

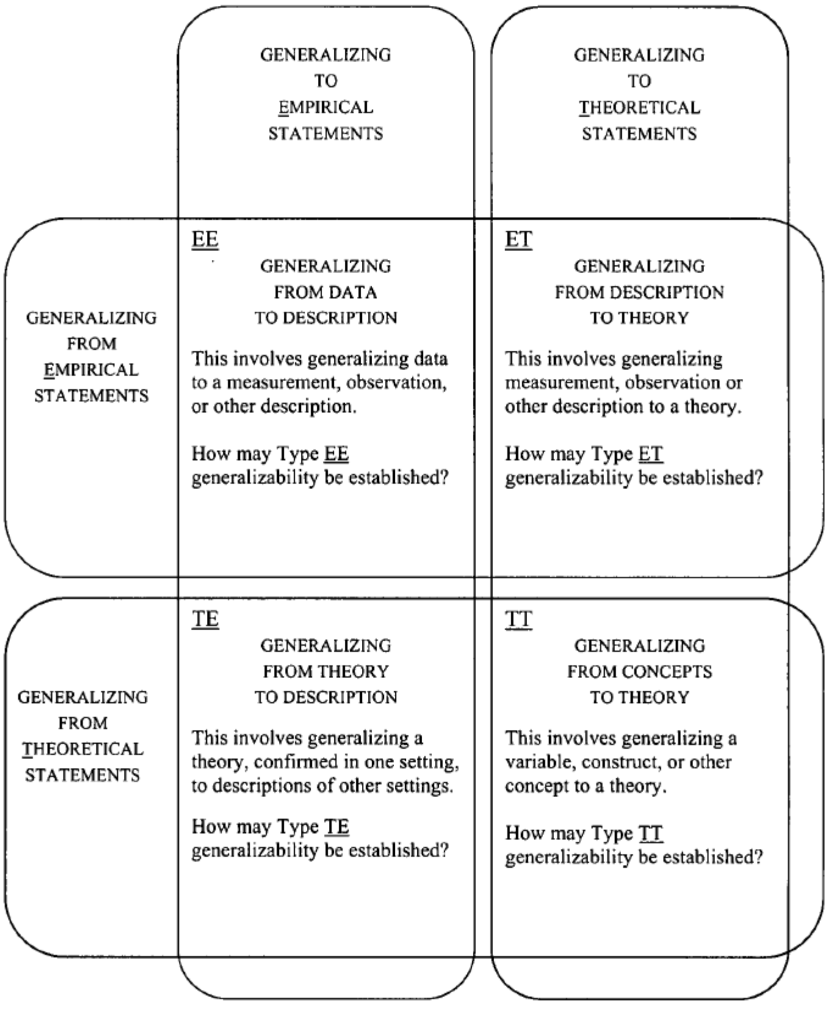

Figure 1: Four Types of Generalizing and Generalizability [16].

Lee and Baskerville [16] analysed generalisability in Information Systems Research. While generalisability is well established in quantitative research, they argue that qualitative researchers also call for generalisability. However, they see their interpretation of generalisability to be too heavily influenced by quantitative research methods and even there the statistical meaning of "generalisability" to be often misinterpreted. Generalisability of sample points in quantitative research is done to a sample estimate, not to the corresponding population characteristic [16]. A generalisation from a sample to population characteristics is not possible. Accordingly, a theory that was developed from case studies cannot be generalised to other cases where the theory has not been tested.

Lee and Baskerville [16] propose a generalisability framework that contains four types of generalising and generalisability (see figure 1). Type "EE" generalises from empirical statements to empirical statements. Examples are the generalisation of data to measurement and the generalisation of a measurement beyond the sample from which the data was collected. Type "ET" generalises from empirical statements to theoretical statements. Examples are the generalisation from measurement to theory and generalising a theory beyond the sample from which the theory was derived. Type "TE" generalises from theoretical statements to empirical statements. This happens when a theory is tested in a setting the theory has not been tested before, e.g. a practitioner using a theory in an enterprise. Finally, type "TT" generalises from theoretical statements to theoretical statements. This occurs when theoretical propositions are developed based on concepts.

2.2 Transferability

Generalisability, however, is only one of the terms used for scientific inquiries for the aspect of applicability [11]. For naturalistic inquiries, "generalizations of the rationalistic variety are not possible because phenomena are intimately tied to the times and the contexts in which they are found" [11]. However, to ensure applicability, transferability of the research results should be achieved: "Yet these facts do not obviate the possibility that some transferability between two contexts may occur because of certain essential similarities between them." [11]

While Lee and Baskerville discuss generalisability both for positivism and for interpretivism, Travis [27] identifies transferability rather than generalisability as a goal in interpretivist research. She clarifies that transferability is not generalisability. Transferability does not give a precise prediction about the applicability of the findings to a different sample. Rather, transferability enables the utilisation of the findings in a different setting. "Transferability represents the degree of transfer 'between sending and receiving contexts' where the sending context is that of the researcher or inquirer." [27] It is left to the scientist doing the transfer to determine the validity in the new context. To achieve transferability, a thick description of the context is needed. "If the thick descriptions demonstrate an essential similarity between two contexts, then it is reasonable to suppose that tentative findings of Context A are also likely to hold in Context B (although, to be safe, an empirical test of that presumption should be made)." [11] Lee and Baskerville do not mention "transferability" at all. Perhaps they subsume "transferabilty" under "generalisability".

3. DESIGN SCIENCE RESEARCH

From our point of view, it is intuitively clear that generalisation and transfer are relevant for design science. In this community, the objects under study, as well as the outputs of research, are the designs themselves. If designs would not be general but merely particular solutions to particular, everyday problems (e.g. of one company), it would be of little relevance to the research community.

3.1 Relevance and generality of Design Science knowledge

Hevner et al. [13] see IS research to act between the environment and the knowledge base (see figure 2). The research has to be applicable in the appropriate environment, and at the same time provide additions to the knowledge base. This knowledge base is used to generate new designs by abduction [28]. As "knowledge becomes 'relevant' when it is context specific" [1] to fulfil business needs, an artefact designed needs to be as specific in respect to people, organisations and technology as possible. The more adapted a design is to a specific setting in practice, the more relevant it is, as instantiations are easier to generate. On the other hand, the more specific a design is, the narrower the scope and the less likely to find a case for another instantiation.

Design science is about creating designs ("design as an artifact" [13] (Guideline 1)) that solve "important and relevant business problems" [13] (Guideline 2). The types of artefacts observed in publications are system design, method, language/notation, algorithm, guideline, requirements, pattern and metric [21].

The research output should be described as a design theory [10; 32]. The publication of a design theory is not the solution itself, e.g. a running software systems or an optimised business process. Rather, a design theory contains the design of a solution, e.g. software architecture or a business process model. If a solution is based on a design, it is an "instance" of the design. A design theory also contains the purpose and scope of the design, specifying for which context instances are supposed to be useful and the utility to be expected respectively.

There seems to be some awareness of the relevance of the level of abstraction in the community. However, generalisation and transfer have not received much explicit attention. The most explicit statements about generalising that we could find were: "The design scientist must be able both to generalize the findings and demonstrate a theoretical contribution." [14] and "Design-science research holds the potential for three types of research contributions based on the novelty, generality, and significance of the designed artifact." [13]. Other

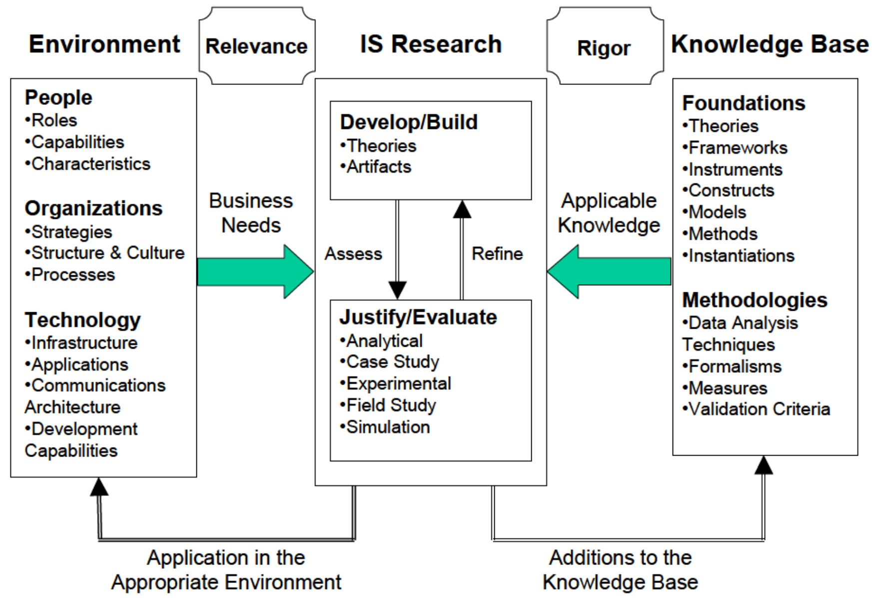

Figure 2: Information Systems Research Framework [13].

Table 1: Types of design according to range of scope.

Design type	Definition	Role in design	Role in research	Examples
Short-range design	Design for a specific setting	An instance (system implementation, method enactment) can directly be derived from the design	First-of-a-kind solution to a relevant problem.	The specification for a CRM system; the software development process for a company
Mid-range design	Design for a specific type of setting	The design can be used to create a short-range design for a particular solution of the same problem domain	Identification of relevant design elements for a particular problem domain	eXtreme Programming, TOGAF, Rational Unified Process, relational database design
Long-range design	General insights about a type of design approach	Educational, as a starting point for dealing with a problem, illustrating a particular design "world-view"	Inform more specific designs	SOA, Object-Orientation, relational data-management, agile software development

Design Research disciplines outside of ISR discuss generalisability and transferability [4; 5].

The limited awareness might also be due to the limited discussion of epistemology in design science [24]. We think that the focus of Rohde et al. [24] onto social practice with the corresponding position of ontological idealism and a consensus theory of truth will lead to knowledge that is only valid in a specific organisation. In that case, no generalisation or aggregation of knowledge would be possible, rendering any prescriptive theory pointless. While we debate the exclusiveness of their opinion, we agree that it is a vital part of design science.

3.2 Types of Designs according to their range

Analogous to the work in [16], we want to identify the different inputs and outputs of generalisation and transfer for design. We believe that this is a first step to better understand what these processes mean for Design Science Research in ISR. We do so by focussing on designs as inputs and outputs.

In the field of sociology, Merton [20] introduces the concept of "theory of the middle range", implying that there are different levels of theory, relative to their distance to empirical observations and stating that "middle range theories" are preferable to more general "total systems of sociological theory" [20]. Merton specifies: "Middle-range theory involves abstractions, of course, but they are close enough to observed data to be incorporated in propositions that permit empirical testing" [20] This concept has been mentioned by other DSR scholars (e.g. [8; 14]), but it remains to be discussed how design research can generate knowledge by moving between different levels of design. To do so, we will first introduce three different "ranges" of design and will discuss how generalisation and transfer happens between these types of design in the next section.

Winter discusses a "tradeoff between the level of solution generity and the problem scope" [33]. Design research needs to produce "situational artefacts" [33] that cover a range of problems that then can be adapted to a problem at hand. We will call this "adapted" type of design *short-range design*: the design is only applicable to the particular situation (e.g. it contains company-specific features). Such a design might be the architecture of a company's CRM system or a company's software development process.

A more general design, that is valid not only for a specific setting, but for the whole type of settings will be called *mid-range design*. Borrowing from Merton's concept of mid-range theory, we postulate that mid-range designs form the basis for a whole range of (situation-specific) short-range designs permitting empirical testing through instantiations. As these designs are of general interest, they form the most common design type observed in research, the "situational artefacts" of Winter [33]. When looking at the design theory literature, especially Walls et al. [32] and Gregor and Jones [10], this level of abstraction seems to be what design theories are supposed to address.

From these mid-range designs, general design principles can be extracted. They are not bound to particular situations and are not bound by individual designs but capture the "fundamentals" from which certain types of designs can be constructed. We will call these principles *long-range designs*. Long-range designs can become paradigms that shape the research agenda of part of a research community and lend their concepts to many different mid-range designs. They often can be found in introductory-level courses and textbooks. An overview of the three design types is presented in table 1.

3.3 Epistemological positions for different types of Designs

Becker and Niehaves [3] propose an epistemological framework, with which they want to capture different philosophical assumptions of IS research efforts. The framework consists of five epistemological questions and offers different answers for each.

The first question asks what the "object of cognition" is. Designers attempt to solve problems in "the real world" and solve problems by creating / manipulating "real-world" artefacts. This corresponds to a position of "Ontological realism". On the other hand, the process of identifying what a problem is usually incorporates the views of the researcher and different stakeholders, which might introduce aspects of the problem based on their perception. This would point more to a position of transcendental idealism or "Kantianism" in the words of [3]. The second question asks what the "relationship between cognition and object of cognition" is. In the context of design this refers to how we can learn about properties of the problem (analysis) and of solution artefacts (validation). "Objective" measures can be

Table 2: Research strategies in Design Science.

Strategy	Affected types	Approach	Research contribution	Validation
Explore new problem	Short-range	Invent design for new problem	First-of-a-kind design offers first design insights on new problem	At least one real-life instance validates utility
Validate mid-range design	Mid-range to short-range	Create new short-range design and validate its utility	Increased generalisability of utility statement	Use of accepted evaluation strategies
Generalise to mid-range design	Short-range to mid-range	Analyse commonalities and differences of short-range designs with comparable purpose and scope and find generalised representation	Captures generalised knowledge in terms of common design elements about a problem domain	The process of identifying similarities and finding generalised representation of concepts. Demonstration of applicability of new mid-range design by creating a new short-range design from it.
Apply out of scope	Mid-range to short-range	Derive short range design from mid-range design and change it to work for new problem	Indication that mid-range design might cover wider scope and possibly first-of-a-kind design	At least on real-life instance validates utility in a setting outside of the original scope
Synthesise mid-range design	Mid-range to mid-range	Analyse commonalities and differences of mid-range designs with comparable purpose and scope and find generalised representation	Make mid-range design better transferable and possibly increase utility	The process of identifying similarities and finding generalised representation of concepts. Demonstration of applicability of new mid-range design by creating a new short-range design from it
Combine designs	Mid-range to mid-range	Merge designs with adjacent purpose and overlapping scope	Create a design with a more comprehensive purpose	The process of combining the designs. Demonstration of applicability of new mid-range design by creating a new short-range design from it
Extract long-range design	Mid-range to long-range	Analyse commonalities and differences of mid-range designs from the same domain and identify common principles	Captures design principles that apply to a whole class of problems	The process of identifying the design principles

made, but phenomena can also be interpreted based on individual predispositions. Hence, both realism and constructivism play a role. The third question asks what true cognition is. "Truth" concerns both the results of analysis and validation. Both correspondence theory (for "objective" measurements) as well as consensus theory (for interpretative results) are relevant. The fourth question asks about the sources of cognition. Designers, as discussed previously both observe and interpret and either activity informs the other. Observations might change interpretation, but interpretation "guides" the observation. This is best captured by "Kantianism". The final question asks how the cognition can be achieved methodologically. In design, a variety of approaches might have to be employed. This includes induction, wherever knowledge is gained by generalizing individual observations; deduction can be necessary if the design is derived from a reference framework and hermeneutics might be employed when a designer transfers knowledge between contexts, and needs to re-interpret statements in the new situation.

The different levels of abstraction in the three ranges of design reflect a difference in the nature of knowledge that is captured on each range and therefore differ in their epistemological position. The above description captures short-range designs as we understand it. Mid-range designs, which according to [20] should also lead to testable hypotheses, are also largely capture by the description. Nevertheless, mid-range designs always refer to short-range designs, either as the source from which a mid-range design is constructed, or as the result, which is derived from a mid-range design. This increases the role of ontological idealism, as the dependence on the concepts of other individuals grows. It also introduces the necessity to harmonise different designs, which leads to a semantic theory of truth [3]. Long-range designs are even further away from the real word. The objects have no direct representation outside of the mind. Their "truth" can only be established consensually, and they represent "a priori" knowledge. This kind of knowledge has large influence when a researcher approaches a new short- or mid-range design, as it provides the categories which shape the perception of the problem at hand.

4. PROPOSAL OF STRATEGIES FOR KNOWLEDGE CREATION, GENERALISATION AND TRANSFER

Our approach of identifying strategies consisted of three steps:

1. Generating candidates, based on the framework of design levels and "scope and purpose",
2. Trying to find at least one published example for each candidate,
3. Pruning the candidate list of those strategies for which we could not find an example.

For our design-level model to be meaningful, we expected to find at least one strategy on each level and/or between each level. The distinction between "similar scope" vs. "different scope" would have to be found in at least one strategy. We have identified seven strategies: one within the short range, three between short- and mid-range, of which ones stretches different scopes, two within mid-range and one between mid- and long-range, as described in the remainder of this section.

At the beginning of any design research effort, a problem is identified for which no solution is available. The problem has not been solved before and cannot be solved by some trivial variation of some other solution. Such a problem would either occur unexpectedly while researching some other problem or as the starting point of a deliberate venture, but in both cases the main focus would be to solve this particular problem, resulting in a short-range design. The design process is influenced by experiences with earlier designs and general theories. The first design would show that the problem does have a solution. Insight gathered during the design process can deliver first insights on the nature of the problem and the range of design alternatives. Hence, **exploring a new problem** is a valid research strategy in early stages of research.

The goal of mid-range designs, either created through generalisation or as an immediate, genuine creation, is to be able to derive specific, short-range designs from them to address concrete problems. Whenever a new short-range design is derived from a mid-range design and it successfully solves the problem at hand, it **validates the mid-range design**. The mid-range design proposes that its application within a certain scope of situations will yield a certain utility and the more situations a design has been shown to work, the more likely it is considered to work for similar new problems. This mode comes closest to the notion of "generalisation" in quantitative science.

Once several short-range designs exist for an existing problem, it might be possible to **generalize** them **to a mid-range design**. For this strategy, a number of short-range designs are analysed for commonalities. The mid-range design is formulated in a way that is more general than the grounding short-range designs. An example for this activity is the creation of design patterns (e.g. [7]). Patterns are parts of re-usable software designs, derived from many individual solutions. The act of generalisation is in itself a creative, design-based act: Elements of the short-range designs must be identified for inclusion, and other elements must be added or changed to work in a more generalised context. Also, the designs need to be considered holistically to grasp their intentions and idiosyncrasies.

A mid-range design might also be transferred to a short-range design outside of the original scope (**apply out of scope**). The designer might realise similarities between the problem at hand and the solution, even if the latter does not claim to solve this problem. As the resulting short-range design is out of scope, the claimed utility of the mid-range design might not materialise. If the solution does show to be successful, it is an indicator that the scope of the mid-range design can be extended.

To create better designs, existing mid-range designs with an overlapping purpose and scope might be analysed to identify the strong points of each and to create a new mid-range design that combines these, in other words, **synthesizing a mid-range design**. This would typically happen whenever several approaches with the same intention have emerged and it becomes obvious that they are not fundamentally different. Since a synthesised design is nevertheless a new design, validation becomes necessary.

To enlarge the scope and/or purpose of a design, designs might be combined into a single design that is more comprehensive (**combine designs**). To arrive at a new design, similar elements in the original designs need to be harmonised and the interface between the individual source designs needs to be defined.

Finally, short-range and/or mid-range designs might be analysed to extract common principles that solve a certain class of problems - to **extracting a long-range design** from these inputs. This would typically happen when the research in a field has progressed and several, possible synthesised mid-range designs have emerged. Those designs would have very basic common assumptions, even if the designs themselves differ from each other. A coherent set of such assumptions would form the paradigm resulting in a long range design. An overview over the strategies can be found in table 2.

The strategies imply a certain order of applicability for each research topic, depending of the topic's maturity, as shown in figure 3. For a new topic, no designs are available. Therefore, exploring a new problem and creating a short range design is a viable strategy. Alternatively, a mid-range design might be created from scratch and validated. As time goes by and the topic remains relevant, several short-range designs become available. Then, mid-range designs can be generalised. In a next step, these mid-range designs can be validated to increate the generalisability of their utility. As time moves on and more and more mid-range designs become available, the design can be synthesised to enhance the utility of the design. Also, as the topic develops and the problem changes, mid-range designs can be applied out of scope or be combined to solve the changed problem. Finally, from a set of mid-range designs of various types (system architecture, pattern, method, etc.) but similar topics, a long-range design can be extracted.

5. CASE STUDIES

For each strategy, we present a paper that uses the strategy to demonstrate that the types of design and the strategies are not merely theoretical constructs but can also be found in research.

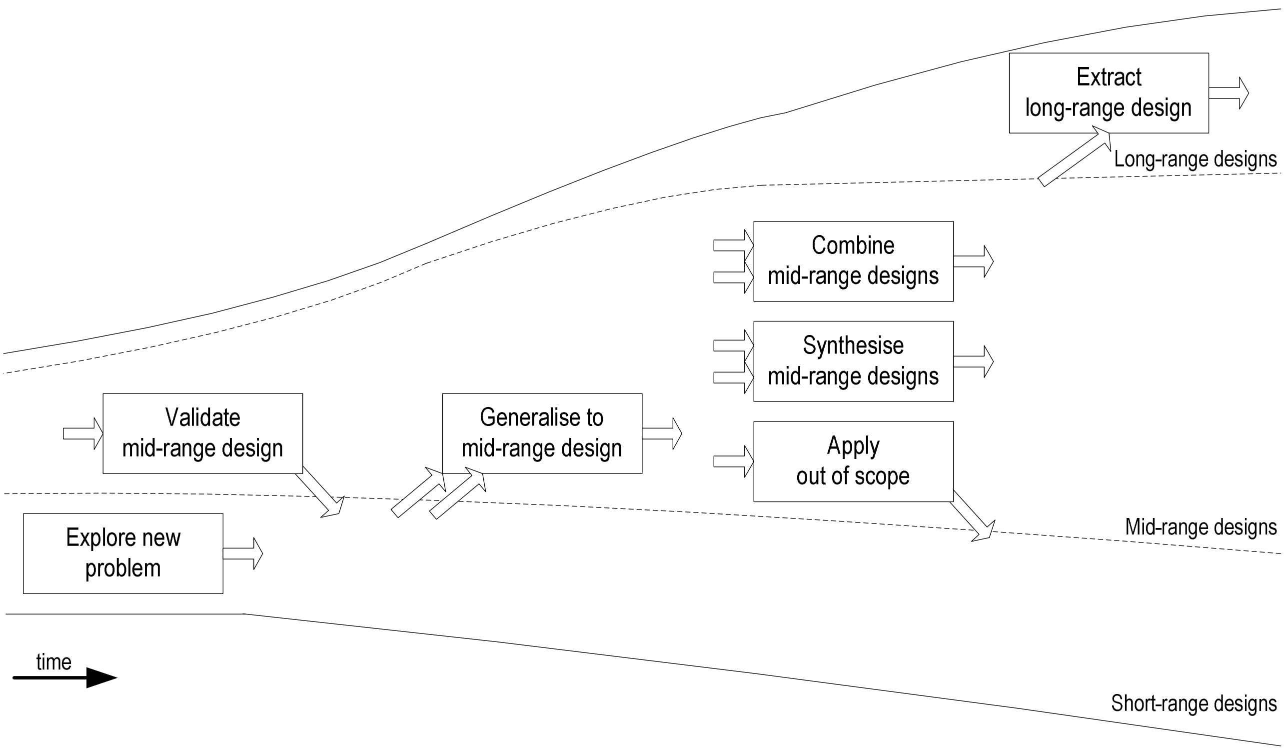

Figure 3: Sequence of design strategy application as design theories accumulate.

5.1 Explore new problem

A good short-range design for a new problem has been published by Spiekermann et al. [26] in their article "SkillMap – A Social Software for Knowledge Management – From Concept to Proof". They start by identifying shortcomings in current designs: "... knowledge management systems (KMS) have failed to fulfil the organizational promises with which they were first introduced." [26] They then identify a theory that promises to better explain human behaviour relevant to knowledge management: "In their seminal work on KM, they accumulate a number of enabling conditions that foster 3rd generation knowledge creation and sharing in companies. These include: intention, autonomy, variety, creative chaos and redundancy." [26] They continue to present a design along the enabling conditions and then present their solution: "This article presents a software called skillMap that was built as a proposition for how 3rd generation knowledge management tools could function." [26] They present the graphical user interface and the architecture of the system. To evaluate user perception, the "user experience through the GUI and the activation of intrinsic motives such as fun and curiosity" were measured.

The paper presents a typical short-range design. Based on theory, a first-of-kind solution is created. The design presented is an abstraction of the solution and therefore tightly bound to the solution. It explains how the different parts of the solution support the enabling conditions. Once more third-generation knowledge management tools have been implemented and the decisive elements are better understood, the designs might be generalised into a mid-range design that is independent of a specific solution.

5.2 Validate mid-range design

Balijepally et al. [2] took the pair programming technique as a mid-range design and evaluated its utility. While pair programming is only one of the techniques that form a software development method, it is independent of any specific method and can therefore be seen as a mid-range theory. Before presenting their own evaluation, they present the results of prior studies on the utility of pair programming. As there is no official utility statement for pair programming, each evaluation has a different operationalisation of utility. The main topics evaluated were software quality, development effort and task complexity. Balijepally et al. [2] then present their research model that evaluates software quality, programmer satisfaction and confidence in performance. They conduct a laboratory experiment with students. They found "that pair performance typically cannot exceed the performance of its best member working individually". They also found that "pairs were more satisfied than both the best and the second-best members of nominal pairs" and that "pairs were more confident in their performance, compared to the second-best members of nominal pairs, but not the best members".

While Balijepally et al. [2] did not create a new design, they evaluated a design to increase the generalisability of the design's utility. Design evaluation is an essential part of Design Science Research, and while it might be argued if evaluation is actually design, without an evaluation the utility of a design cannot be demonstrated.

5.3 Generalise to mid-range design

A good mid-range method design to manage the company-wide application architecture that is generalised from the short-range designs for "Credit Suisse Financial Services", "Die Mobiliar" and "HypoVereinsbank" has been published by Hafner and Winter [12] in their article about a management method for the company-wide applicaton architecture. The aim of the paper is to design a consolidated method. After discussing general requirements, they discuss four existing methods for the management of application architectures. They then present three company case studies where the implemented management process has been analysed. Based on the existing methods and the case studies, a consolidated method is derived.

The method published by Hafner and Winter [12] looks at three short-range designs extracted from case studies to identify common elements and idiosyncrasies. They then consolidate the common elements into a method that focuses on the elements that are likely to be important for all instances of the method, leaving out elements that are specific to a certain case. Thereby transferability is increased, as it is more likely to focus on the relevant elements.

5.4 Apply out of scope

The UN/CEFACT Unified Modeling Methodology (UMM) is a mid-range design in form of a method to model B2B processes. It specifies how to model interactions and the information exchanged between different entities. The scope of the method uses B2B interactions. Dietrich [6] wanted to see if the UMM also has utility when used internally by companies, outside the scope of the original design. To verify his thesis, he applied the UMM to processes internal to a company. He created a short-range design for a German capital investment company. By instantiating the design, he was able to demonstrate that the UMM has utility outside of its declared scope.

The transfer of design knowledge out of scope will regularly be performed in practice, where practitioners use any design knowledge available to solve a given problem, despite the declared scope of the design. Dietrich [6] is one of the few researchers who scientifically performed this transfer and demonstrate the usefulness of the transferred design.

5.5 Synthesise mid-range design

Offermann and Bub [22] looked at existing mid-range methods to design systems according to the service-oriented architecture (SOA). For each method, they discussed which parts of the SOA and of the software development lifecycle are covered. They continued to identify weaknesses of the existing methods. Based on the existing methods, they then proposed a new mid-range method to design SOA-systems that overcomes the weaknesses. For the relevant activities in the new method, they discuss which existing SOA-method it is based on.

To incrementally advance knowledge in an established domain, synthesising an improved mid-range design from existing mid-range designs is common practice in research. The publication of Offermann and Bub [22], is a good example for such a synthesis. Usually, after the synthesis, the new mid-range design is validated to ensure its utility and to demonstrate that the new design is indeed an improvement.

5.6 Combine designs

A combined mid-range design has been published by Sowa et al. [25] in their paper "Integrated Information Security Risk Management – Merging Business and Process Focused Approaches". They introduce the existing approaches Business Oriented management of Information Security (BORIS) and Operational Risks in Business and IT (ORBIT). The focus of BORIS is "to handle ... business oriented ISM issues" [25], while ORBIT aims "to control operational risks in business processes in regard to information technology" [25]. The authors then propose a merged design as a generic data model for the integrated information security risk management. The integration point of the two approaches is the control management where in both cases a scorecard evaluation of security and risk drivers is done. The merged design fulfils all requirements on information security management.

The design of Sowa et al. [25] combines business driven and process oriented information security risk management into a single design. The new design has a more general purpose and a larger scope than the original designs. Because it fulfills all the requirements, it can be expected to yield a higher utility than each of the original designs.

5.7 Extract long-range design

Legner and Heutschi [17] published a survey of service-oriented architecture (SOA) design principles. They analysed nine publications from the domain of SOA and extracted ten design principles grouped in four classes: "interface orientation", "interoperability", "autonomy / modularity" and "business suitability". For each of the nine publications they identify which design principles are mentioned. The publications do not focus on a discussion of the design principles. Rather, they propose method and/or technologies for SOA that are directly transferable to solve a company problem. The design principles extracted are more general and form the basis for more specific SOA designs.

By extracting general design principles from concrete design, the scope of the design is not changed. However, such design principles do not directly solve any business problem and therefore also have no direct utility. They form the basis for a whole class of solutions. Other such examples of design principles are object-orientation with a whole set of supporting technology (e.g. c++), modeling notations (e.g. UML) and methods (e.g. xxx) and relational data models (MySQL, entity-relationship-model, database normalisation).

6. DISCUSSION

The concept of generalisation in positivist research is used to infer from a sample to another sample e.g. taken by future researchers. For design theories, this kind of generalisation can be applied to a utility statement, affirming the utility of a design for a set of problems [31]. For example, by creating more instances of a design and measuring the utility of the instance, the probability that the next researcher or practitioner creating an instance will also find the utility increases. This notion of generalisation assumes that the observed variables are to some extent similar and remain unchanged within the whole population of observed entities, so that observing a subset of entities can plausibly approximate the conditions in the population. This mode of knowledge creation was only one ("validate mid-range design") of the seven we propose in this article. In design science "'artificial phenomena' have to be created by the researcher" [14]. Designs capture not only the structure of theses artificial phenomena, but also the goals and intentions of those creating them. When creating a solution for a problem at hand, a design will guide the creator but will leave room for and will actually require creativity and considerable thought. As such any design is open to change and adaptation and the original design does not necessarily exclude other uses. Three of our strategies acknowledge this (combine, synthesize mid-range design and apply out of scope). Creation of something new, without reference to an existing design, is also possible at any time (create new short-range design). The long-range design, finally, is not so much a theory as a world view for a particular set of design problems. As seen in the example above, the principles are valuable, but neither lead to any specific design nor make any specific testable predictions. Nevertheless, they have value. For example, they can offer a basis for education and to evaluate critical parts in an unfamiliar design. While the three levels of abstraction were deduced theoretically, we were able to find published examples on all levels, as can be seen in table 1 and section 4.

The fact that the majority of our strategies are concerning mid-range design is coherent to other views on design theory (e.g. [9]). This is explainable through the re-use potential of mid-level designs: Short-range designs solve the immediate problem at hand but contain many details that are idiosyncratic for the solution. It might offer inspiration and insights for designers that have similar problems at hand, but at the outset it is unclear whether the amount of help gained through the design outweighs the effort to understand and then discard design parts irrelevant to the new solution. Long-range designs, on the other hand, might not be available for a particular kind of design; and even if available, it might be the problem itself might not be addressed by a general design principle or the translation of such a principle into specific design is not straight-forward. Also, as already mentioned, long-range designs are hardly verifiable.

7. CONCLUSION

While the research process in design science is well established, it is still unclear how design knowledge can be created in a cumulative way that goes beyond individual solutions to individual problems. The problem arises from the requirement to create designs that are relevant to practice but at the same time contribute to the knowledge base. In this paper we presented three types of designs that offered different levels of abstractions in terms of distance between solution support as codified in a design and problems.

We then presented strategies how to create knowledge based on the different abstraction levels and how to generalise and transfer designs. By means of presenting published examples of all seven strategies, we demonstrated that the theoretically derived design types and strategies do not only exist on paper, but can be found in practice. The strategies help researchers in identifying and performing Design Science Research projects as they offer criteria to categorise their design, depending on a research topic's maturity. By focussing not only on the creation of new designs for specific business problems but by also developing existing designs to become more general, we hope to contribute towards design science becoming a more cumulative science which can move forward.

The strategies proposed by us are relevant to all types of Design Science Research outputs. Therefore, the operationalisation of the strategies remain rather generic. We have only included research strategies for which we could find examples. It is possible, and we expect further strategies to be identified. For certain types of outputs more specific guidelines might be given. For example, when combining mid-range method designs, there might be integration points such as the method's role models or the artefacts produced by the methods a researcher could look into to create the combined design. Both extending and detailing strategies offer opportunities for future research.

8. REFERENCES

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