Creating Design Knowledge: The Interplay Between Kernel Theory and Practice

Full research paper

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Abstract

One essential element of design science research (DSR) is kernel theory, which plays a critical role in the development of design knowledge. Kernel theory is employed in the theoretical grounding process to justify and guide the development of emergent design knowledge. Another common way to justify design knowledge is empirical grounding. However, these two grounding processes are not mutually exclusive. We argue that there exists a dynamic interplay between the application of kernel theories as a deductive inference strategy and the analysis of empirical data resulting in insights from practice as an inductive inference strategy. Based on an analysis of a DSR project involving nine companies, we have examined this interplay to propose guidelines. These guidelines aim to assist in navigating the complexities of theory and practice, ultimately supporting the development of robust and innovative artefacts. We state that our findings contribute to knowledge about how kernel theories can interplay with practice.

Keywords. Design Science Research, Kernel Theories, Design Knowledge

1 Introduction

Design Science Research (DSR) is a widely accepted research method within Information Systems (IS) (Hevner et al. 2004; Grego and Hevner 2013; Venable et al. 2013). One essential element of DSR is kernel theory, which plays a crucial role by providing well-established theories from the natural or social sciences that inform and guide the design of new artefacts (Walls et al. 1992; Kuechler and Vaishnavi 2008; Rose et al. 2019; Cronholm and Göbel, 2019). Our definition of kernel theory relies on a) a general definition of theory presented by Lee et al. (2011, p.2), which reads, “patterns that explain the relation of one property with another are searched and proposed, and the truth of such proposed patterns is examined through experience” and b) an adapted definition for DSR, which reads “the underlying knowledge or theory from the natural or social or design sciences that gives a basis and explanation for the design” (Gregor and Jones 2007, p.322). Moreover, kernel theories can be grand theories or mid-range theories (Kuechler and Vaishnavi 2008).

Our literature review has uncovered several roles for kernel theories to play in the development of design knowledge. One role is to support the building of the artefact, and another is to explain and justify the emergent design knowledge (Gregor and Jones 2007). Furthermore, by grounding design principles in kernel theories, the rigour and credibility of DSR contributions are enhanced (Möller et al. 2022). Moreover, kernel theories are not the only way that can explain and justify emergent design knowledge (Goldkuhl and Cronholm 2010; Cronholm, 2005). Goldkuhl and Lind (2010) discuss three ways to justify design knowledge: empirical observations, knowledge of theoretical character and the design knowledge itself. These correspond to three grounding processes: empirical grounding, theoretical grounding, and internal grounding. Empirical grounding involves evaluating the effectiveness of the application of design knowledge. Theoretical grounding means that the design knowledge is grounded in explanatory kernel theories. Internal grounding involves checking of internal cohesion and consistency (ibid.).

We recognise the importance of applying different grounding processes of design knowledge. However, these grounding processes *are not separated from each other*. We state that there exists *an interplay* between applying kernel theories as a deductive inference strategy and analyses of empirical data or insights from practice as an inductive inference strategy. We define an interplay as how two or more things affect each other (Oxford Learning Dictionaries 2025). It describes a dynamic relationship where elements reciprocally influence one another. Therefore, we argue that the interplay should be utilised to improve the quality of design knowledge. Our statement is supported by Cronholm et al. (2023), who added that understanding this interplay is essential when planning the research design of DSR projects as inductive, deductive, or abductive processes. By effectively exploiting the interplay between kernel theories and empirical data, researchers can ensure that their design knowledge is theoretically sound and practically applicable. This exploitation of the interplay can lead to more robust and innovative artefacts. Furthermore, a deeper understanding of this interplay can help DSR scholars navigate the complexities of theory and practice in their research projects.

However, our literature review has revealed a lack of knowledge regarding how the interplay between kernel theory and practice could support the emerging design knowledge. This lack of knowledge is problematic because it limits researchers' ability to systematically integrate theoretical and empirical insights in the development of design knowledge (e.g., design principles, IT artefacts). Therefore, our study aims to develop prescriptive (how-to-do) and normative (what to achieve) knowledge about the interplay between kernel theory and practice. This means that our study aims to develop guidelines that can utilise this interplay in order to improve design knowledge. It also means we need to understand kernel theories and their roles. Our research question is two-folded and reads: a) What interplay exists between kernel theories and practice? and b) What guidelines could be formulated to effectively utilise the interplay in the development of design knowledge? Our research question is supported by Möller et al. (2024), who argue that design researchers are confronted with several questions on how, when, and why to use a kernel theory. The purpose of the guidelines is to provide insight into how kernel theories can interplay with empirical data collected from practice and to support researchers to utilise kernel theories better to develop DSR knowledge in their DSR projects.

Our target group is primarily DSR scholars. Nevertheless, we also state that our findings could be considered by scholars using other research approaches because the development of theory usually involves both theoretical and empirical grounding. In the following section, we present a literature review followed by a section describing the research method. Next, we describe our findings, discussion and conclusion. Then, we present our findings, and finally, we draw conclusions.

2 Literature Review

In order to find out what is known about the role of kernel theory when it interplays with practice, we were inspired by the literature review method suggested by vom Brocke et al. (2015). We searched articles in the Scopus database and used the keywords "kernel theory" and "design science research", which returned 94 documents". Unfortunately, many of these articles did not discuss the role of kernel theory and even less the interplay between kernel theory and practice. Therefore, we decided to apply backward and forward searches, which are the most common techniques used to identify relevant articles (ibid.). Backward searching is a method for examining reference lists in order to collect appropriate publications (Webster and Watson 2002). Forward searching means collecting relevant publications that have cited these papers (ibid.) In total, we have identified 28 relevant articles. In the second step, we synthesised the literature by grouping statements describing similar roles of kernel theory (vom Brocke et al. 2015).

Role 1: Backdrop to explain the problem and underlying phenomena. Venable (2006) assert that that kernel theory and theorising should play a key role in DSR. Moreover, as theories shape our understanding of the real world, kernel theories and other knowledge (e.g. technological knowledge) about the relevant phenomena affecting or creating the problem are instrumental in understanding the problem space that commonly forms the starting point for a DSR process (Raabe et al. 2021: Drechsler and Hevner 2022). Goldkuhl (2004) explicitly uses the concept of explanatory kernel theories. One reason is that a crucial role for kernel theories is the grounding of the design knowledge in general explanatory theories.

Role 2: Guidance for Artefact Development. Nunamaker (1991) and Simon (1996) state that kernel theories advise design solutions and Walls et al (1992) state that they govern design requirements. Kernel theories could be either kernel product theories (govern design requirements) or kernel process theories (inform the design process) (Gregor and Jones 2007). The role of kernel theory is to ensure that the artefacts are not only innovative but also grounded in established knowledge. In particular, they support the derivation of meta-requirements for a meta-design (Möller et al. 2022). In addition, kernel theories guide the development of artefacts by offering theoretical insights that shape the design process or product(s) (Avdiji et al. 2019). Moreover, kernel theories should be ingrained into artefacts (Sein et al. 2011). Kuechler and Vaishnavi (2008) emphasises that kernel theories inform both the effect we seek in the artefact (the 'Goal') as well as suggesting the 'Prescribed action'.

Role 3: Justification of Design Choices. Kernel theories serve as a basis for justifying design decisions. By linking design choices to established kernel theories, researchers can provide a robust rationale for their designs, enhancing the credibility and rigour of their work (e.g. Lukyanenko and Parsons 2013). However, an abundance of kernel theories can lead to an oversupply that obstructs effective kernel theory selection rather than assisting it (Möller 2024). Moreover, another similar concept is justificatory knowledge, which is broader than kernel theories. Justificatory knowledge can include a range of knowledge outside the borders of theory, such as practitioner knowledge (Gregor and Jones 2007).

Role 4: Justification of Design Principles. Goldkuhl and Lind (2010) state that design theories and other forms of design knowledge (such as design principles) need to be justified, and they propose three types of knowledge sources for justification: empirical observations, other knowledge of theoretical character (e.g. kernel theories) and the design knowledge itself. Furthermore, Rose et al. (2019) present a process for developing design principles from kernel theories. The authors argue that kernel theory plays an important role when deriving normative and prescriptive statements, which are then used to refine, justify and organise elements of design principles. Moreover, kernel theories provide the foundational knowledge that can justify the formulation of design principles (Möller et al. 2022; Cronholm and Göbel 2022).

Role 5: Enhancing Theoretical Legitimacy. Kernel theories help enhance the theoretical legitimacy of design knowledge (Walls et al. 2004). Although, Walls et al. (2004) do not explicitly use the term "legitimacy", they posit that design theories should be based on natural and social science theories (referred to as kernel theories) since the "laws" of the natural and social world govern the components that comprise an information system. Goldkuhl (2004) state that kernel theories could be integrated into design theory and, as such, are considered part of design theories. However, in contrast to Walls et al. (1992), Goldkuhl does not conceive kernel theories to be a necessary part of design theories. A kernel theory might be part of a design theory but does not need to be so (ibid.). This position is shared by Venable (2006, p.11), who state that "First, it seems unnecessary that a design theory should incorporate kernel theories ... This does not mean that we should not *use* kernel theories when forming new design theories (or hypothesising them), just that they aren't a necessary part of design theories". Moreover, kernel theories ensure that the knowledge is not only practical but also contributes to the broader body of knowledge by linking DSR contributions with theoretical foundations. In addition, theoretical grounding serves as the link between emergent design knowledge and kernel theories (Goldkuhl 2004; Goldkuhl and Lind; 2010).

Role 6: Facilitating Communication. Möller et al. (2022) state that the role of kernel theory is often challenging to grasp, comprehend, and most importantly operationalize. Therefore, they argue that authors: 1) proposing design principles should make unambiguously clear if and which kernel theory was used (clarity), 2) should state how many kernel theories and why they were selected to inform a part or multiple parts of design principle development (transparency) and 3) should indicate which part of design principle development is informed by which kernel theory (e.g. meta-requirements or design principles derived from kernel theory). Furthermore, kernel theories enable design researchers to communicate design theory independent of the applied science from where it was derived (Peffers et al. 2018). That is, kernel theories facilitate communication among researchers by providing a common theoretical language that helps to share and compare research findings.

Role 7: Target of extension and refinement. DSR projects not only develop artefacts but are also committed to testing and refining of their underlying kernel theories (Kuechler and Vaishnavi 2008). These authors also state that theory from other fields that intends to explain or predict phenomena of interest are refined into mid-range theories within DSR in information systems. Moreover, theories from other fields are often so narrowly derived as to be more suggestive than useful as given, and that refinement of the theory in the act of development is required to give the theory direct applicability to IS design efforts (ibid., p.490). Kuechler and Vaishnavi (2008, p.491) explicitly state that "Through the praxis of the DSR project, new empirical knowledge and knowledge from kernel theories is translated from the kernel domain to become unique IS theories". In addition, the refinement and extension of kernel theory can be considered as a key contribution of DSR (Hovorka 2010), alongside the creation of artefacts (Hevner et al. 2004). For example, emergent design often arises from insights gained through practice, which may challenge the underlying kernel theory. These challenges can inform and constitute a basis for the extension of existing kernel theories.

Role 8: Continuously guiding the research process. Kernel theories along with other justificatory knowledge play a vital role across an entire DSR process, continuously guiding the DSR knowledge journey through possibly several cycles or iterations until the final contributions to theory and practice are formulated (Drechsler and Hevner 2022; Akoka 2023). This continuous guidance is illustrated in the abductive DSR model described by (Cronholm et al. 2023), which confirms that kernel theories are not just used in a single phase or stage of the DSR process. Möller et al. (2024) presents three tensions that can obstruct the continuously guidance of the research process: paradox (mutually reinforcing opposites that seem logical in isolation but absurd together), Ambivalence (facing uncertainty over which of several appealing opposites should be chosen) and dilemma (equally appealing opposites that come at the expense of one another. To resolve the tensions, they suggest several generic and specific responses (confer Möller et al. (2024) for a detailed description).

In summary, our literature review identified several key roles that kernel theories play in the iterative development of innovative artefacts in DSR projects. These multiple roles highlight the critical importance of kernel theories and their significant relationship to design knowledge. However, we can conclude that the analysis of the literature primarily discusses the *role of kernel theory and not the interplay between kernel theory and empirical data identified in practice*. Therefore, this interplay is under-researched, which underscores the knowledge gap discussed in section 1.

3 Research Method

We analysed a DSR project, which involved four researchers and nine companies. The project was conducted over a period of three years. The problem experienced by the companies was insufficient innovation capability to improve their service offerings. The innovation capability suffered from a lack of service perspective and skills regarding data-driven innovation. Due to these shortcomings, the DSR project searched for digital tools that could support the companies' innovation capability. However, the DSR project could not identify any appropriate digital tools. Therefore, the DSR project decided to build a digital tool supporting the companies' innovation capability.

The building of the digital tool relied heavily on relevant kernel theories and empirical data collected from the nine companies. This fact also created excellent opportunities to study the interplay between kernel theories and empirical data, which is the purpose of this paper. The DSR project was guided by the Action Design Research (ADR) method (Sein et al. 2011), which consists of four stages: 1) Problem Formulation, 2) Building, Intervention and Evaluation, 3) Reflection and Learning, and 4) Formalising of Learning. Each stage further comprises several research tasks. The companies belonged to multiple sectors, were of different sizes (small, medium, and large), and consisted of service providers or customers in the private or public sector. The private sectors represented were the automobile industry, telecommunications, and IT.

We collected data from the following sources: a) notes taken from discussions among the researchers and practitioners during project meetings and workshops, b) audio-taped interviews of company representatives, and c) project documentation. In total, we analysed data from 15 project meetings and 23 interventions in the practitioners' organisations (workshops).

In order to respond to the first part of the research question, *what interplay exists between kernel theories and empirical data*, the collected data was analysed using the Grounded Theory Method (GTM) (Strauss and Corbin 1990). GTM consists of three phases: open coding, axial coding and selective coding. We analysed the data during these phases and created categories and sub-categories regarding the interplay between kernel theories and empirical data. This analysis was supported by the action paradigm model consisting of three meta-categories: *conditions, actions, and consequences* (Strauss and Corbin 1990). A *condition* defines a specific circumstance and corresponds to the questions "why" or "what" (i.e. why the interplay between kernel theories and empirical data took place). An *action* describes something that occurs under particular circumstances and corresponds to the question "how" (i.e. actions taken to address the condition). A *consequence* is a result dependent on the conditions and actions. It corresponds to the question of "what happens" if specific actions are carried out (i.e. consequences of the actions taken). The result of the analysis was a number of superior categories (see section 4).

In Section 1, we stated that the purpose of our study was to identify prescriptive (how to do) and normative (what to achieve) knowledge that supports understanding of the interplay between kernel theory and practice. To respond to the second part of the research question, *what guidelines could be formulated to effectively utilise the interplay in the development of design* knowledge, we followed Goldkuhl's (2004) view of prescriptive and normative knowledge. Goldkuhl (2004, p.63) states that a prescriptive statement does not only refer to a certain kind of act. It also includes a reference to a goal that is assumed to be attained when performing this kind of act". The relationship between an act and goal is formally stated as, "Perform act A in order to obtain goal G" (ibid.). This implies a close relationship between prescriptive and normative knowledge.

4 Findings – Identified categories

Our analysis of the DSR project has resulted in six categories that describe the interplay between theory and practice. This interplay occurred in several stages of the research process. As mentioned in Section 3, we have structured each category according to the action paradigm model consisting of three meta-categories: conditions, actions and consequences. Below we are elaborating on each category individually, and at the end of the section we present a figure summarising the findings (see Figure 1).

4.1 Category 1: Identification of Knowledge Gaps

Condition: As mentioned in Section 3, the companies experienced a need for improving their innovation capability. They explicitly suffered from a lack of service perspective and skills regarding data-driven innovation. Therefore, the goal was to search for an existing or develop a new appropriate digital tool that could support them in this matter.

Action: Based on the problem and goal formulation, the DSR project commenced with a market analysis to identify suitable digital tools supporting service and data-driven innovation. The market analysis resulted in that no suitable tools were identified. In the next step, the DSR project searched for design knowledge (e.g., design principles, guidelines, recommendations) that could inform how such digital tools could be built. Moreover, the DSR project searched for specific kernel theories that were explicitly developed to inform the design of such tools. The result was the same; no suitable design knowledge was found.

Consequence: The DSR project concluded that there was a lack of design knowledge regarding how to build digital tools that could support improvement of innovation capability. This meant that the DSR project had identified a knowledge gap. Based on this insight, the DSR project decided to build a digital tool and formulated the following research question: How should a digital tool be designed to spur the discovery of service innovations? Moreover, the identification of the knowledge gap confirmed the need for further research and motivated the DSR project to develop design knowledge for a class of problems and a class of systems that support service innovation. As a result of our analysis of the DSR project, we state that there was a dynamic interplay between the problem and goals and the search for design knowledge and specific kernel theories.

4.2 Category 2: Identification and Selection of Kernel Theories

Condition: The DSR project identified a need to learn more about a service perspective and data-driven innovation. This meant that the DSR project needed to identify relevant kernel theories that could assist in building a digital tool supporting innovation capability. These theories could comprise explanatory knowledge (i.e., suitable theories explaining factors affecting innovation capability), manipulability knowledge (i.e., knowledge about means to improve these factors), or prescription knowledge (i.e., actionable knowledge on how to improve innovation capability) (Avdiji et al. 2019). Initially, members of the DSR project identified a vast number of kernel theories to guide the explanation of empirical data. However, due to several appealing options, there was uncertainty about how to select the most appropriate ones. Möller et al. (2024) describe several tensions regarding the selection of kernel theories. One of these tensions is called the "picking paradox", which could exist when there is an oversupply of kernel theories. As a result, it was not obvious how to make a selection and the DSR project experienced a need for a systematic approach to select relevant kernel theories.

Actions taken in the DSR project: To identify possible kernel theories, the DSR project explicitly used the keywords in the problem formulation. To make a selection among the identified kernel theories, the DSR project applied practical and communicative rationalities when selecting kernel theories (Wallace and Kiesewetter, 2024). Practical rationality is concerned with performing actions and making decisions that are coherent with goals and values (ibid.). The purpose of communicative rationality is to find solutions in dialogue where the goal is to reach consensus through argumentation rather than to manipulate or dominate others (Habermas, 1985). The DSR project explicitly utilised the formulations of the purpose of the project, problem formulation, research question, project goals, and knowledge gap to inform the selection of kernel theories.

Consequence: We discovered that the elements such as purpose, research question, project goals, knowledge gap, and practical and communicative rationalities interplayed when identifying and selecting kernel theories. Additionally, the discussion of the practical and communicative rationalities of kernel theories constituted a learning process for the DSR project. In a reciprocal manner, these elements provided input to systematic discussions, while these discussions refined the formulations of the research question, purpose, and project goals. The practical and communicative rationalities contributed to identifying and agreeing upon appropriate kernel theories, while rejecting less relevant theories or those that were overly broad. The practical rationality also contributed to ensuring theoretical coherence, which meant that the selected theories aligned well and had no contradictions. Examples of selected kernel theories include digital innovation (e.g. Yoo et al. 2012; Nambisan et al. 2017), service-dominant logic (SD-Logic) (Vargo and Lusch 2004; Lusch and Nambisan 2015) and data-driven innovation (Jetzek et al. 2014; Cronholm et al. 2017).

4.3 Category 3: Formulation of Design Hypothesis

Condition: The DSR project experienced a need to identify explicit support for formulating a design hypothesis. A design hypothesis is a statement proposing a potential solution to a design problem (Hevner and Chatterjee 2010). Often a design hypothesis includes design principles (as nascent design theory) and an artefact (as a carrier of design knowledge). In the DSR project, the purpose of the design hypothesis was to govern the building of the digital tool, articulate design principles, and provide a clear direction for the DSR process.

Actions taken in the DSR project: The formulation of the purpose, research question, project goals, and knowledge gap, together with the selected kernel theories, formed a point of departure for formulating a design hypothesis. The first step was to specify meta-requirements. A meta-requirement corresponds to a class of goals to which the design theory is applicable (Walls et al. 1992). The DSR project identified statements in the selected kernel theories and interviews of practitioners that were reformulated as meta-requirements. These meta-requirements primarily addressed generic goals concerning the functionality of a generic solution (artefact). Examples of meta-requirements specified for the class of systems were a) design to take both customers' needs and companies' resources into account, and b) design to support individual and shared goals for collaboration. Another part of the design hypothesis referred to emerging design principles. A design principle is prescriptive in nature and constitutes the basis for action (Baskerville and Pries-Heje 2010). Furthermore, design principles should include knowledge about creating instances of a class of artefacts (Sein et al. 2011). That meant the DSR project formulated generalised design principles informed by kernel theories and practice. The DSR project developed three generalised design principles: a) design for liquefaction (support developers to design functionality that help actors to mobilise and decouple resources in order to make them available for actors to utilise through the digital tool), b) design for pairing (encourage service providers and customers to jointly pair, combine, and recombine digital resources in order to co-create solutions holding a novel value proposition) and c) design for opting (support organisations when they jointly evaluate and opt-in or opt-out of one or more novel problem-solution pairs co-created).

Consequence: We identified that the formulation of the design hypothesis was based on the meta-requirements, which in turn were based on the interplay between kernel theories and empirical data collected from interviews. More specifically, statements identified from kernel theories and practice were compared and integrated into the design hypothesis. This meant that both the design of the digital tool (the artefact) and the emerging design principles relied heavily on insights from both kernel theories and analysis of data. In this way, the design hypothesis was theoretically and empirically grounded, which provided additional rigour.

4.4 Category 4: Evaluation of Design Hypothesis

Condition: In order to evaluate if the design hypothesis was valid, the DSR project applied a qualitative approach involving the analysis of statements from kernel theories and data collected from nine companies. This meant that a large number of theoretical statements and data were collected. Therefore, the DSR project needed appropriate theoretical and methodological support to conduct a structured evaluation of the digital tool.

Action: The DSR project searched for a well-established and practical approach that could support the evaluation of the design hypothesis. The DSR project selected the Framework for Evaluation in Design Science (FEDS) (Venable et al. 2016). FEDS is based on evaluation theory and is explicitly developed for DSR studies. The DSR project created an instance of FEDS adapted to the DSR project's specific situation. Due to the DSR project’s empirical nature and motivations to conduct a rigorous evaluation, the following choices were made: a) natural evaluation, b) combined formative and summative evaluations, c) empirical evaluation episodes, and d) selection of specific criteria for validating the design hypothesis. While FEDS provided a set of generic evaluation criteria from the DSR literature (e.g., utility, novelty, ease of use, effectiveness, efficacy), the DSR project considered them to be too abstract to be useful in the specific situation. The DSR project thus drew on the meta-requirements and kernel theories to further instantiate these evaluation criteria. For example, the following criteria were derived when evaluating the digital tool: comprehensibility (e.g., are statements prescribing the collaborative process understandable), form and function (e.g., are internal rules and interaction easy to understand), relevance (is the digital relevant to service providers’ business), effects (what are the effects of using the digital tool) and service provider and customer relationship (what are the impact on the between the service provider and the customer).

Consequence: We identified an interplay between FEDS (including its underpinning theories) and empirical data collected from the participating companies when evaluating the design hypothesis. FEDS provided rigour and a clear focus for the evaluation. At the same time, the analysis of the data provided a basis for justifying the design hypothesis. The project comprised three iterations, which meant that the design hypothesis was successively refined based on insights from practice. Another consequence was that FEDS ensured that the evaluation process was consistent across all the participating companies.

4.5 Category 5: Explanation of data

Condition: The empirically collected data from the participating organisations constituted a basis for developing the digital tool and design principles. However, the initially selected kernel theories underpinning the formulation of the design hypothesis could not fully explain the collected data. This meant that these kernel theories were insufficient, and there was a need for complementing theories. For example, the empirical data clearly expressed a need to develop support for stronger collaboration between service providers and customers and models for measuring capability maturity.

Actions taken in the DSR project: Due to the shortcomings of the initially selected kernel theories, the DSR project consulted additional kernel theories. The DSR project selected additional kernel theories regarding service ecosystems (Vargo et al. 2017) and capability maturity (Software Engineering Institute 2002). The search for supplementary kernel theories was repeated for each iteration of the DSR project.

Consequence: We realised that there was an interplay between kernel theories and practice to support the explanation of data that could not be explained at first. Empirical data that kernel theories could not explain prompted the DSR project to search for additional kernel theories. The additional kernel theories provided support for explaining data that could not be explained by the initially selected kernel theories. Another consequence of the interplay was that the DSR project learned more about the studied problem and meta-requirements, which provided input to the refining of the problem and the research question. In addition, the iterative process of analysing data and selecting additional kernel theories helped the DSR project to continuously align the kernel theories with empirical data. In turn, this meant that the design hypothesis was continuously refined through theoretical and empirical justification.

4.6 Category 6: Making Kernel Theory Actionable in Context

Condition: The DSR project experienced shortcomings regarding the selected kernel theory SD-Logic. SD-logic presents 11 foundational premises and five axioms, which excellently inform about *what* to do (Vargo and Lusch 2016). However, these foundational premises were not explicitly developed for an IT context and did not provide explicit guidelines concerning *how to* innovate services.

Actions taken in the DSR project: The DSR project utilised the empirical findings as evidence to develop guidelines that could be applied when using SD-logic. These guidelines were regarded as a complement to S-D logic, and they were explicitly connected to specific foundational premises (ibid.).

Consequence: We identified an interplay between the kernel theories and empirical data regarding the extension of kernel theories and their practical applicability. The selected kernel theories demonstrated shortcomings and potential for improvement, while empirical data was used to develop an extension of the kernel theory (i.e. SD-logic). In this way, the extension was empirically grounded. The extension of SD-Logic meant that prescriptive knowledge was added, which extended SD-Logic's practical applicability. Contributing to the extension of kernel theory meant that the project closed a knowledge gap between theory and practice.

4.7 Summary of Findings

The purpose of Figure 1 is to summarise and present an overview of the six categories and their relationships to kernel theories and practice. The overview is organised into two dimensions. The horizontal dimension consists of the categories' relationships to kernel theory and practice. The vertical dimension suggests how the categories could be linked to a possible order of DSR processes. For example, the DSR process could start with identifying a knowledge gap and end with extending kernel theories.

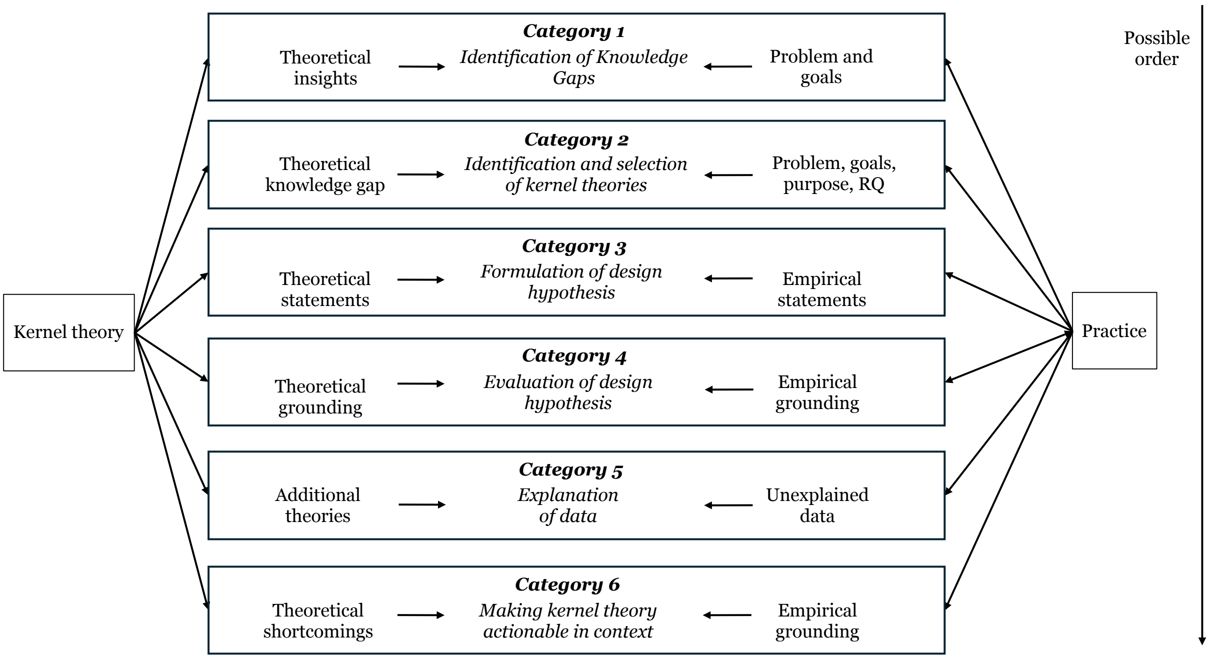

Figure 1: Summary of identified categories and their relationship to kernel theory and practice

5 Formulation of Guidelines

Based on the identified categories and the literature analysis, we have formulated prescriptive and normative knowledge in terms of six guidelines to utilise the interplay between kernel theories and practice (see Table 1). The purpose of the guidelines is to support robust and innovative artefacts and help DSR scholars navigate the complexities between theory and practice. As mentioned in Section 3, we have followed the formula suggested by Goldkuhl (2004): "Perform act A in order to obtain goal G" (columns 1 and 2). The guidelines are empirically justified by the analysis of the DSR project including an explicit link to each category (column 3) and theoretically justified by an explicit link to the roles of kernel theories identified in the literature study (column 4).

Guideline		Empirical justification	Theoretical justification
Action	Goal		
1. Formulate the knowledge gap based on the interplay between identified problems and goals, and insights from theories.	To ensure that the problem is previously unsolved and that new territory is explored.	Category 1: Identification of knowledge gaps.	Role 1: Backdrop for explaining the problem and underlying phenomena.
2. Identify and select kernel theories based on the interplay between the knowledge gap and practical and communicative rationality.	To ensure relevance and usefulness of the selected kernel theories.	Category 2: Identification and selection of kernel theories.	Role 1: Backdrop for explaining the problem and underlying phenomena. Role 5: Enhancing Theoretical Legitimacy.
3. Formulate the design hypothesis based on the interplay between statements identified in kernel theories and practice.	To ensure that the emerging design knowledge builds further on existing knowledge.	Category 3: Formulation of design hypothesis.	Role 2: Guidance for Artefact Development. Role 3: Justification of Design Choices. Role 5: Enhancing Theoretical Legitimacy.
4. Evaluate the design hypothesis based on an interplay between theoretical insights and empirical data.	To ensure that ideas for redesign that are theoretically and empirically grounded.	Category 4: Evaluation of design hypothesis.	Role 4: Justification of Design Principles. Role 5: Enhancing Theoretical Legitimacy.
5. Search for additional kernel theories based on the interplay between data that could not be explained and shortcomings in previously selected kernel theories.	To ensure that additional kernel theories can explain the collected data.	Category 5: Explanation of data.	Role 4: Justification of Design Principles. Role 8: Continuously guiding the research process.
6. Refine kernel theories to make them actionable based on the interplay between shortcomings of selected kernel theories and empirical grounding.	To make contributions to the selected kernel theories.	Category 6: Making kernel theories actionable in context.	Role 7: Target of extension and refinement.

Table 1. Guidelines for utilising the interplay between kernel theories and practice

To support the practical utility of the guidelines, we have related them to specific stages and tasks in the ADR method (see Table 2). The first column presents the guidelines. The second column describes which of the four ADR stages is relevant. Each ADR stage consists of different tasks, and the third column specifies a specific ADR task within each stage where the guideline could be considered. The numbering of the tasks corresponds to the numbering of tasks in the ADR method. We have not added goals for the ADR tasks in Table 2 because they correspond to the goals described for each guideline in Table 1.

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Guideline	ADR stage	ADR task
Guideline 1	Problem Formulation	Task 1: Identify and conceptualise the research opportunity Task 2: Formulate initial research questions.
Guideline 2	Problem Formulation	Task 3: Identify contributing theoretical bases and prior technology advances.
Guideline 3	Building, Intervention and Evaluation	Task 2: Select or customise BIE form.
Guideline 4	Building, Intervention and Evaluation	Task 3: Execute BIE cycle(s).
Guideline 5	Building, Intervention and Evaluation	Task 4: Assess need for additional cycles, repeat
	Reflection and Learning	Task 1: Reflect on the design and redesign during the project Task 2: Evaluate adherence to principles Task 3 Analyse intervention results according to stated goals.
Guideline 6	Formalisation of Learning	Task 4: Articulate learning in light of theories selected.

Table 2. Guidelines and their relationship to specific tasks in the ADR method

6 Discussion and Conclusion

Our overall conclusion is that the interplay between kernel theory and practice ensured that the contributions of the DSR project were both innovative and grounded in established knowledge. This interplay supported the credibility and practical relevance of the developed design principles and the digital tool. Based on the analysis of the DSR project and the literature review, we have suggested six guidelines. Following Goldkuhl (2004), the guidelines consist of one prescriptive (action) and one normative part (what-to-obtain). We argue that these guidelines should be considered to effectively utilise the interplay between kernel theory and empirical data when developing DSR knowledge.

We can conclude that the actions taken in the DSR project utilised the interplay between kernel theories and empirical data, which provided rigour to the contributions of the DSR project in terms of:

- *Theoretical and empirical grounding*: The interplay between kernel theories and empirical data offered additional rigour to the emerging design knowledge. The interplay created enhanced conditions for validating the DSR knowledge to be innovative, theoretically sound and empirically relevant.
- *Justification and validation*: The interplay between kernel theories and empirical data provided extended justification of design choices made during the development process. The kernel theories provided a framework for explaining why the developed design principles are expected to work. The empirical data provided evidence that the design of the artefact was relevant to practice.
- *Reciprocal approach*: The development of design knowledge could be characterised as a reciprocal approach equally guided by kernel theory and empirical findings. The reciprocal approach encouraged a constant focus shift between kernel theories and data. For example, reciprocal actions were frequent when meta-requirements and evaluation criteria were derived from both kernel theories and empirical data to formulate initial and refined design hypotheses.

Our literature review found that existing DSR knowledge primarily focuses on the different roles of kernel theory. Therefore, we state that our findings extend existing knowledge by suggesting six guidelines regarding the interplay between kernel theory and practice. Moreover, the interplay between kernel theories and empirical data consists of two directions, *from kernel theory to practice and from practice to kernel theory*. Our analysis of these directions reveals that the direction from kernel theory to practice is more dominant regarding the categories: identification of knowledge gaps, formulation of the design hypothesis and explanation of data. On the contrary, the direction from practise to kernel theory is more dominant regarding the categories: identification and selection of kernel theories, evaluation of the design hypothesis and making kernel theory actionable in context.

Furthermore, Table 1 shows that sometimes more than one kernel theory role underpins one of our guidelines, and several kernel theory roles underpin more than one guideline, suggesting a complex relationship between the two sides of the interplay.

We recognise that the generalisation of qualitative single research projects is a well-known problem (e.g. Lee et al. 2011; Baskerville et al. 2019). However, based on our general understanding of DSR, we posit that design knowledge in any form of DSR relies heavily on the interplay between kernel theories and empirical data. Moreover, the analysed DSR project was guided by the ADR method, which is an established DSR method. As the roles that theories and empirical data play in ADR do not differ from DSR in general, we further posit that other DSR projects could benefit from considering our findings and applying our guidelines as well. As future research, we call for broader studies to complement our study by further validating our findings by adding new insights or modifying our categories and guidelines.

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