Abductive Design Science Research: The Interplay between Deduction and Induction

Research-in-progress

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Abstract

Design science research (DSR) aims to generate knowledge about innovative solutions to real-world problems. DSR studies usually involve inductive, deductive or abductive inference strategies to generate design knowledge. However, applying these strategies has often remained implicit, which means that the transparency of the research processes could be questioned (e.g. openness, honesty). This study focuses on abductive DSR, which is often regarded as a combination of inductive and deductive strategies. Based on our literature review, we can conclude that there is a lack of prescriptive support for how to conduct abductive DSR. We have also identified that the concept of abduction is omitted in well-known DSR frameworks/methods. To address this research gap, our study applies a qualitative content analysis to analyse two abductive DSR PhD theses. The analysis outcome is a conceptual model describing central relationships and an abductive DSR process model illustrating movements between the theoretical and empirical domains.

Keywords Abduction, design science, design science research, action design research, abductive reasoning

1 Introduction

Design Science Research (DSR) has gained much interest since the seminal paper published by Hevner et al. (2004). Nowadays, DSR is a widely accepted research method within Information Systems (IS) (Gregor and Hevner 2013; Cronholm and Göbel 2019). Our literature review has revealed that several DSR studies have been conducted as qualitative studies (e.g. Cater-Steel et al. 2019; Pascal and Renaud 2020). We have also identified that the design knowledge developed in DSR studies is based on inference strategies such as induction, deduction and abduction. Inductive analysis is a form of logical reasoning that involves inferring a general conclusion from empirical observations (Recker 2013). This means that the patterns and categories created emerge from empirical data. For example, inductive analysis is supported by Grounded Theory (Strauss and Corbin 1990).

Deduction refers to making inferences about particular cases from more general rules or theories Kennedy and Thornberg (2018). It is usually driven by hypothesis derived from theories and then tested by collecting and analysing data (e.g., Walsham 1993; Klein and Myers 1999). The theories selected are sometimes called kernel theories in DSR studies (e.g. Gregor and Jones 2007; Kuechler and Vaishnavi 2012). Abductive research is driven by empirical data and hypotheses in parallel and equal engagement with empirical data and existing theory (Timmermans and Tavory 2012; Thompson 2022). In addition, Kennedy and Thornberg (2018) state that abduction is about discovering new concepts, ideas and explanations by finding *surprising* phenomena, data, or events (i.e., anomalies) that cannot be explained through pre-existing knowledge. This means that abduction is a process of resolving surprising data (anomalies, unexpected data) and identifying possible explanations. In addition, abductive research means constantly moving back and forth between data and theories and making comparisons and interpretations when searching for patterns and the best possible explanations (Pierce 1974; Bryant 2009; Kennedy and Thornberg 2018). Consequently, abductive research entails both inductive and deductive processes (Minnameier 2010; Gregory and Muntermann 2011; Åsvoll 2014).

In this study, we will focus on abductive approaches in DSR. One reason is that our literature review has revealed that several DSR studies have applied some form of abductive approach (e.g. Mustafa and Sjöström 2013; Haj-Bolouri et al. 2018; Cronholm and Göbel 2022). A second reason is that, when conducting qualitative research, scholars should consider the relationship between data collection and analysis as well as between theory and data (Kennedy and Thornberg 2018). A third reason for focusing on abduction in DSR studies is that it resonates well with Gregor (2009) and Gregory and Muntermann (2011), who emphasise that the importance of abduction in theory building should be recognised. Unfortunately, Gregor (2009) and Gregory and Muntermann (2011) do not give any advice on how to conduct abductive DSR. A fourth reason is that DSR scholars must employ abduction in addition to creativity and imagination (Gregor 2009). These reasons make abduction in DSR different to abduction research in general. The creative aspect is prominent because the design of an artefact always reflects the circumstances in the context where it is to be used (e.g., Beyer and Holtzblatt, 1999; Holtzblatt, 2007) and the complex combination of "making" and "knowing" in DSR require unique methods of producing general knowledge (Baskerville et al. 2015).

Our literature review has uncovered that whether the research approach is inductive, deductive or abductive is often implicit in most DSR studies. This does not necessarily mean that there are no clear descriptions of the way in which the design knowledge is developed. However, it means that readers of articles with implicit inference strategies need to analyse methodological descriptions themselves in order to fully understand how they are applied. To a large extent, the credibility of qualitative studies depends on the transparency of the research processes (e.g., openness, honesty) (Lincoln 1995). Therefore, the omission of essential methodological concepts such as induction, deduction and abduction, means that there is a risk that the transparency of the theory developed will be reduced (Dimov et al. 2022).

We have also found that abductive research in general has been discussed previously in the IS literature (e.g., Alvesson and Kärreman 2007; Timmermans and Tavory 2012; Kennedy and Thornberg 2018). However, our view is that there is a need for contextual knowledge regarding specific DSR characteristics. One argument is that several prominent DSR articles highlight the interplay between the theoretical and empirical domains (Hevner et al. 2004; Baskerville et al. 2009; Sein et al. 2011). In other words, the development of IT artefacts and design principles is usually fully dependent on both existing kernel theories and organisational intervention (e.g. Hevner et al. 2004; Hevner 2007; Baskerville et al. 2009; Sein et al. 2011). The interplay means that emerging design knowledge should be grounded in both theoretical insights and empirical evidence.

We have also analysed the existence of methodological advice on how abduction can be conducted in some well-known DSR methods (e.g., Peffers et al. 2007; Baskerville et al. 2009; Sein et al. 2011). The

purpose of all these DSR methods is to support the development of IT artefacts and to create innovative design knowledge. In addition, several DSR methods are process-oriented and recommend phases/stages that should be followed during DSR projects. Moreover, in different ways, they stress the importance: a) of being able to follow clear steps in process models (e.g., Peffers et al. 2007), b) improving human organisations, especially with consideration for social aspects, through a technological artefact (e.g., Baskerville et al. 2009) and c) developing IT artefacts based on the intervention in organisations and theoretical inscription (e.g., Sein et al. 2011). In addition, several DSR scholars state that the development of IT artefacts and design knowledge relies heavily on the interplay between theory and empirical data (e.g., Hevner 2004; Sein et al. 2011; Kuechler and Vaishnavi 2012; Gregor and Hevner 2013). Our analysis of the DSR methods identified that they occasionally, or not explicitly, discuss *the interplay* between existing theories and empirical data. This means there is a risk that users of these prominent DSR methods will not reflect upon how existing theory and empirical data should interplay when designing research studies.

In summary, we have identified three problems regarding abductive DSR: a) the description of the inference strategy used in DSR studies is often omitted, b) there is a lack of specific knowledge regarding abductive DSR and c) there is a lack of methodological advice concerning abductive processes in several well-known DSR methods. Based on the problems mentioned above, our short research-in-progress paper aims to develop prescriptive knowledge for abductive DSR. Gregor and Jones (2007) state that prescriptive knowledge focuses on *how to do something*. The purpose of our study is to develop prescriptive knowledge through two models (artefacts). According to van Aken (2005), prescriptive models can be seen as solution concepts to be professionally used in process design. Moreover, Gregor and Hevner (2013) state that "Offering these artifacts at an abstract level means that they can be operationalized in a number of other unstudied contexts, thus greatly increasing the external validity of the research" (p.341). The following research question has guided our search for prescriptive knowledge: *How can abductive DSR processes be conducted?*

The contribution to theory consists of prescriptive abductive DSR knowledge that could be regarded as an entry into the debate concerning the interplay of theories and empirical data. The contribution to practice consists of prescriptive models. Our intention is primarily to support novice DSR scholars. In the following section, we present a brief literature review followed by a description of the analysis unit and the research method. Next, we describe our analysis, discussion and conclusion.

2 Literature Review on Abductive DSR

Due to the page limit for short papers, we could only discuss a few additional articles to the articles presented in section 1 regarding abductive DSR. This meant that a complete literature review following a structured literature review method could not be conducted. However, given the constraints of a short paper, our ambition has been to provide a sufficient understanding of what is previously known regarding abductive DSR. In order to find relevant articles, we applied "snowball sampling" (e.g. Noy et al. 2008), which means that we applied backward referencing to identify papers that could be of interest. We have found that several DSR scholars state that all design practices are abductive practices (Kuechler and Vaishnavi 2008a), that abduction plays a key role in dealing with design questions (van Aken 2014) and that abductive logic generates truly new ideas (Menchaca et al. 2014). Moreover, Kuechler and Vaishnavi (2008b) have developed high-level conceptual models involving DSR theory development, which touches upon different inference strategies. In addition, Goldkuhl (2004) discusses the development of design knowledge in terms of multi-grounding, which involves inductive processes consisting of empirical grounding and deductive processes consisting of theoretical grounding of design knowledge. He states that the interaction between empirical, theoretical and internal grounding is imperative when developing design knowledge. Finally, Gregor and Muntermann (2011) discuss theorising strategies that can be employed in DSR to make a theoretical contribution. Their study found that abduction, deduction, and induction play a central role in DSR. All these articles have provided insightful knowledge for our study. However, our literature review has not identified prescriptive models supporting the realisation of abductive DSR.

3 Description of the Analysis Unit

Our analysis unit consisted of two PhD theses that applied abductive DSR in a qualitative fashion. Although the term abduction is not applied in these PhD theses explicitly, the design knowledge emerged from an extensive interplay between existing theory and empirical data. Both these PhD theses were conducted as monographs. The reason for selecting monographs is that the opportunity to analyse detailed descriptions of abduction processes is greater than in articles published in scientific journals

with page limitations. Another reason for selecting these theses is that the authors were available. This means there were excellent possibilities of gaining clarifications when needed. The third reason was that both PhD theses had applied a widely used DSR method (Action Design Research (ADR), Sein et al. 2011) which is widely used DSR method. The fourth reason was that the selected theses heavily relied on both empirical data and theoretical insights. The theses selected are: "Designing Digital Resourcing" (Göbel 2019) and "Designing Human-Centered Hybrid Decision Support Systems" (Cao 2023). The research processes were similar for the two PhD theses, although some differences were identified. Both consisted of three iterations, and there was a frequent interplay between kernel theories and empirical data.

The purpose of the first PhD thesis was to design an IT artefact for digital resourcing and to develop design principles enabling the development of IT artefacts for digital resourcing. The following design principles were formulated: design for resource liquefying, design for pairing, and design for opting. The research question read: How should digital resourcing systems be designed to spur the discovery of digital innovations? The study lasted for eight years and involved frequent researcher-practitioner collaboration. Moreover, it dealt with a large volume of empirical data and utilised kernel theories such as resource-based theory, service-dominant logic and digital innovation.

The purpose of the second PhD thesis was to design an IT artefact for hybrid decision support. A hybrid decision-support system is based on human and artificial intelligence collaboration. Another purpose was to develop design principles assisting the development of IT artefacts for hybrid decision support. The following design principles were formulated: design for utilising human capabilities, design for utilising machine capabilities, design for guided combination, design for humans at the centre and design for complementary capabilities. The research question read: How should human-centred hybrid decision support systems be designed? The study lasted for six years. Empirical data was collected from two companies, and the kernel theories selected were decision-support theory, human-centred artificial intelligence, management theory, human decision-making and psychology.

4 Research Method

In order to develop prescriptive knowledge for how to carry out abductive DSR, we have reconstructed the research processes in the two PhD theses. We applied qualitative content analysis (e.g., Mayring 2014), and we have in particular been searching for: a) how the interplay between sequences of induction and deduction was organised, b) when the shifts between induction and deduction took place, and c) what role existing theory and empirical data played. We have conducted the following steps: (a) Analysis of the two PhD theses (involving discussions with the authors of the theses) in order to get the overall idea of the research approach, (b) Reconstruction of the abduction processes in order to make implicit abduction processes explicit, and (c) Reconciliation of the individual analyses in order minimise biased interpretations. The analyses and reconstructions conducted in steps (a) and (b) were conducted individually by the authors of this paper. Step (c) was conducted as a joint effort. In interpretive approaches such as text-based analysis, researchers might interpret data differently (Walsham 1993). Therefore, we decided to reduce risks regarding biased interpretation by organising several meetings where individual reconstructions were compared in order to reach consensus.

5 Prescriptive Models for Abductive DSR Studies

The purpose of this section is to analyse and present prescriptive knowledge regarding how to carry out abductive DSR. Based on an analysis of the PhD theses, we have developed a) a conceptual model that describes the relationships between the theoretical domain, the empirical domain and emerging design knowledge and b) a process model that illustrates how the design knowledge was developed through the abductive interplay between kernel theories and empirical data.

5.1 The abductive DSR conceptual model

Based on the reconstructions of the PhD theses, we have derived a conceptual model (see Figure 1). The purpose of the model is to support an understanding of central concepts and their relationships and to provide prescriptive generic knowledge of how to conduct abductive DSR in various contexts. As illustrated in the box "Emerging design knowledge", we identified a relationship between the development of the IT artefact and the design principles. The emerging design principles governed the development of the IT artefact. Concurrently, the IT artefact constituted a carrier of design knowledge that could be tested through a hypothesis. This meant that the feedback from the evaluation of the IT artefact was also used to evaluate the design principles. In other words, there was a mutual dependency between the development of the IT artefact and design principles. Moreover, the gaps in the emerging

design knowledge created a need for consulting theories (theoretically informed), and the gaps also informed about what data to collect next and where to find them (theoretical sampling). This means that the analysis of the feedback created further deductive and inductive analysis.

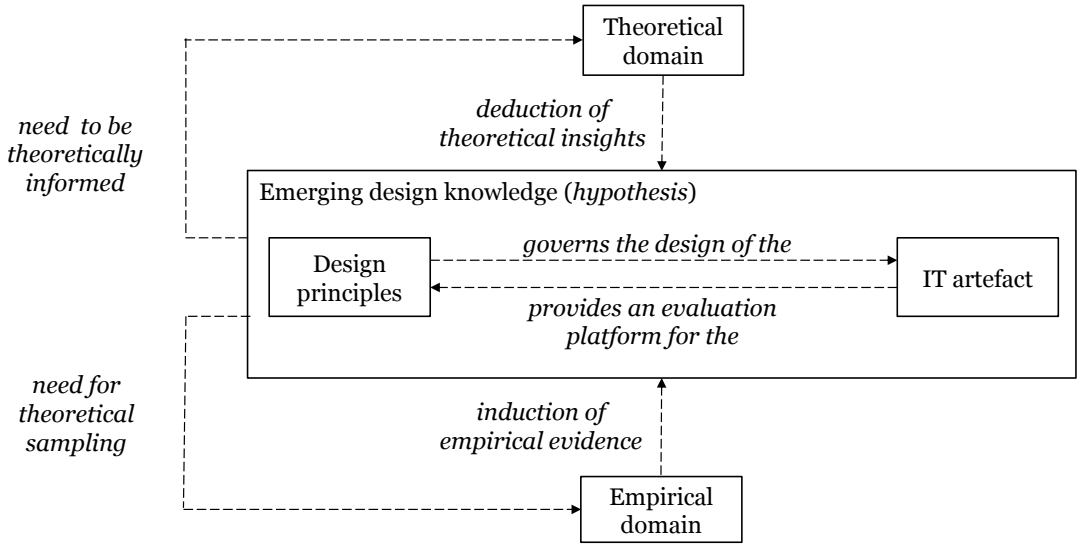

Figure 1: The abductive conceptual model

5.2 The Abductive DSR process model

The purpose of the process model presented in this section is to present the process logic for how to conduct abductive DSR. The point of departure for developing the abductive process model was the four stages in the ADR method (Problem Formulation; Building, Intervention and Evaluation (BIE); Reflection and Learning; and Formulation of Learning. In the next step, we added the abductive movements involving concepts and actions identified in the analysis of the two studies (see Figure 2). Below, we describe each action related to a specific ADR stage in the abductive process.

Problem Formulation: We have found that both PhD theses started within the *empirical domain* in order to identify a problem that existed in practice. It is clearly stated in the ADR method that "The trigger for the first stage is a problem perceived in practice or anticipated by researchers" (Sein et al. 2011, p.40). This means that a *surprise* that could not be explained by pre-existing knowledge was identified and needed to be resolved. In order to identify whether theoretical support existed to solve the problem, the next step was to *scrutinise existing theory*. Our analysis of the PhD theses also identified a research gap regarding solutions to the problem identified in practice.

BIE iterations: Sein et al. (2011) state that theories should inform the development of the IT artefact and that the researcher should "Identify contributing theoretical bases and prior technology advances" (p.41). In both PhD theses, the identification of relevant theories that could assist in solving the problem preceded the building of the IT artefact and the development of the design principles. In DSR studies, purposeful theories are often referred to as kernel theories. The initial theoretical analyses supported the PhD theses to build the first version of the IT artefact and the design principles. In other words, a *deductive movement* was conducted. We also identified that the IT artefact and the design principles were developed reciprocally. This first version was regarded as an *initial hypothesis*. After the *initial hypothesis* was formulated, the participating organisations evaluated the IT artefact, resulting in feedback which involved searching for the "best possible explanation".

This meant that an *inductive movement* was made. In the following BIE iterations, the *surprises* identified in the stage Reflection and Learning were used as a base to consult additional kernel theory. This meant that a *deductive movement* was made. The additional kernel theory and the analysis of the feedback from the previous BIE iteration governed the redesign of the IT artefact and design principles. This action is similar to what is referred to as theoretical sampling (Glaser and Strauss 1967), which is a way of collecting data and deciding what data to collect based on the theory and categories that emerge from your data. This meant that a *refined hypothesis* was formulated. Next, the *refined hypothesis* was evaluated by collecting more data which meant that another *inductive movement* was made.

Reflection and learning iterations: Sein et al. (2011) state that "The reflection and learning stage moves conceptually from building a solution for a particular instance to applying that learning to a broader

class of problems" (p.44). Both PhD theses utilised the feedback from evaluating the IT artefact as input to reflection and learning. The feedback was analysed and categorised according to the Grounded Theory Method (Strauss and Corbin 1990). In both PhD theses, these categories supported the identification of anticipated and unanticipated consequences (*surprises*). The *surprises* were valid for both the IT artefact and the design principles. Moreover, the feedback also revealed a need to consult additional kernel theory that had not been previously analysed.

Formulation of Learning: In both the PhD theses, the stage Formulation of Learning was entered when there was a saturation in data, and the researchers and practitioners jointly agreed that the IT artefact provided utility for its purpose. This also meant that no further *surprises* were identified. Data saturation is reached when there is sufficient data to draw necessary conclusions, and further data collection will not produce value-added insights (Glaser and Strauss 1967*)*. Both the PhD theses state that saturation was reached after three iterations. In order to *verify the hypothesis*, further reflections of the comparisons were made between the emergent design knowledge and existing theory and empirical data. This meant that both *inductive and deductive movements* were conducted.

Other actions: The final action identified in both PhD theses had to do with the modification of the problem formulation according to surprising insights. The arrow at the bottom of Figure 2 illustrates this action. In abductive studies, it is not unusual that the initial research question is modified. Goldkuhl and Cronholm (2010) state that "There must be possibilities for refining the formulations of the question in the progress of the study". Similarly, Sein et al. (2011, p.44) state that "It is also important to adjust the research process based on early evaluation results to reflect the increasing understanding of the ensemble artifact. (p.44).

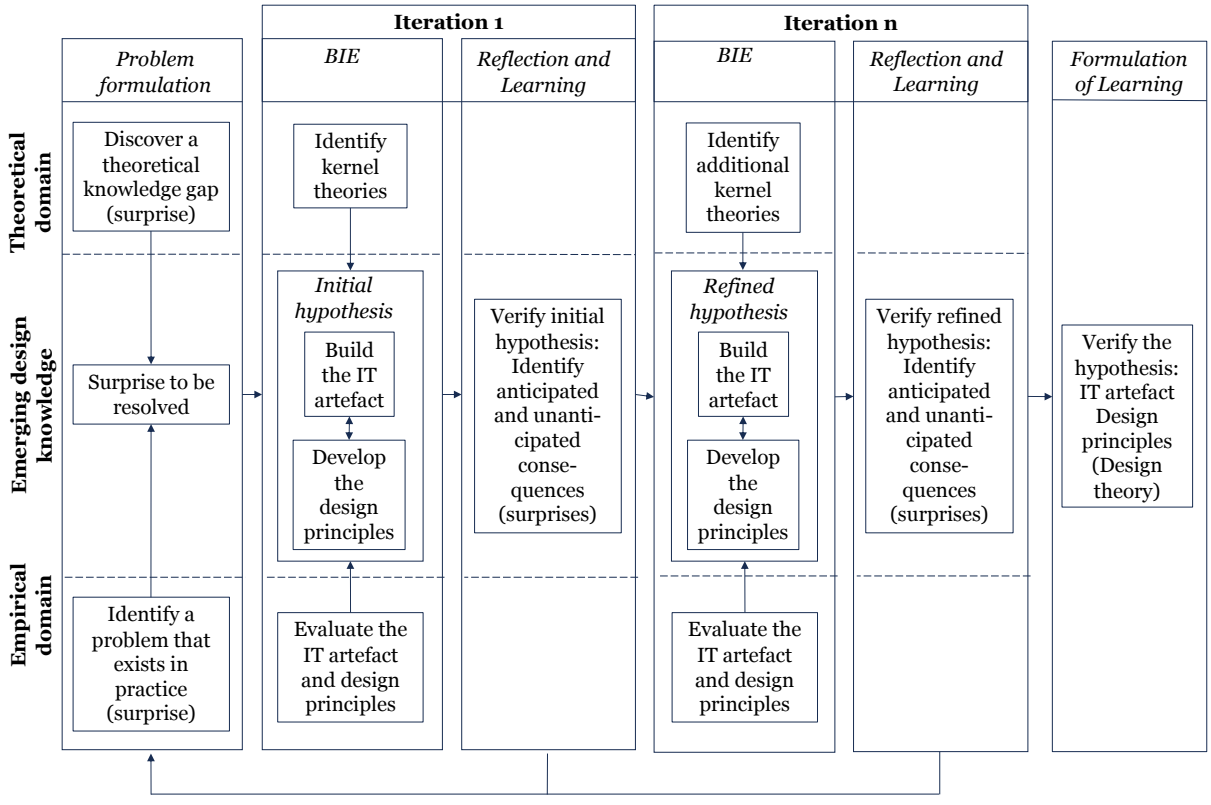

Figure 2: The abductive DSR process model

6 Discussion and Conclusion

The purpose of our research effort was to respond to the research question: *how can abductive DSR processes be conducted*? We argue that our study makes several contributions to the field of abductive DSR. The first contribution is that we have found that the DSR process, represented by ADR in this study, fits well with the abductive approach. On the one hand, abduction supports DSR researchers with a valuable cognitive process that allows them to generate hypotheses, find surprises, construct explanations, and navigate the complexities of both the empirical and theoretical domains. On the other hand, ADR supports researchers with structure and specific activities that allow researchers to combine deduction and induction efficiently and seamlessly. Moreover, we found that abduction in DSR supports

curiosity, creativity, and critical thinking, spurring the research progress in the theoretical and empirical domains. The second contribution consists of the abductive conceptual model, which illustrates the relationship between the development of design principles and IT artefacts. The model also illustrates how the development of design principles and IT artefacts relate to theory and empirical data.

The third contribution consists of the abductive process model describing the moves between theoretical and empirical domains in DSR processes. We have found that the iterative ADR process enables multiple moves between the theoretical and empirical domains, fostering the rigour and reliability of the final research result. The abductive moves are presented in a process model showing: 1) How sequences of deduction and induction interplay and support knowledge to emerge throughout the research process, 2) When each move takes place in the DSR process and 3) Actions related to the interplay between empirical data analysis and extant theory analysis.

The practical implications of our contributions are that the two abductive models contribute prescriptive knowledge and should enable novice DSR scholars to understand how and when to make the abductive moves that constitute abductive DSR. We state that these two models complement prior knowledge concerning abductive DSR which has been developed by Goldkuhl (2004), Kuechler and Vaishnavi (2008b) and Gregor and Muntermann (2011), (see section 2). These articles provide excellent knowledge on DSR abduction, but they lack detailed prescriptive knowledge. Our study can be characterised as research-in-progress. The generalisation of qualitative single-case studies is a well-known problem (e.g. Lee et al. 2011; Baskerville and Pries-Heje 2019). In our case, the models presented are based on the analyses of two PhD studies. Therefore, as future research, we suggest a broader study that builds further on the models we have suggested in this short paper. For example, further research could take a deeper process perspective and provide more details concerning the interplay between induction and deduction.

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