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FORMS OF DISCOVERY FOR DESIGN KNOWLEDGE

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FORMS OF DISCOVERY FOR DESIGN KNOWLEDGE

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Abstract

The article at hand analyses an often disregarded aspect of design science research that is how design knowledge is actually built or, more precisely, how new design knowledge is discovered. In the article we distinguish abductive and inductive forms of discovery. We describe how inductive and abductive discoveries are dealt with in traditional science and how these two forms of discovery have been discussed in Information Systems Design Science Research literature. By means of a case study we specifically illustrate the impact of a chosen mode of discovery on validity, utility, generality, and innovativeness of a problem solution. We find that the strength of inductively discovered design knowledge is that its validity, utility, and generality can be proven more easily than that of abductive discoveries. However, inductively discovered design knowledge often suffers from a smaller degree of innovativeness.

Keywords: design science research, forms of discovery, induction, abduction, design knowledge.

1 Introduction

In information systems research (ISR), not only descriptive, explanatory, and predictive theories are developed, but also design theories (Gregor, 2006). For most theory types, the process of theory development can be divided into two parts: *theory building* and *theory testing*.

A very similar conceptual distinction was developed in the philosophy of science; there the *context of discovery* is discerned from the *context of justification*. This distinction can be traced back at least to Reichenbach (1935), if not earlier (for an exhaustive discussion, see Hoyningen-Huene (1987)). The parts of a theory development process that scientifically justify a theory are separated from those that do not. As an illustration, consider the example of the German scientist Kekulé whose discovery of the hexagonal structure of the benzene molecule was inspired by a dream in which he saw a snake trying to bite its own tale (Rothenberg, 1995). Of course this context of discovery does not comply with any scientific standard. Indeed, Kekulé had to justify his discovery after his dream with scientific methods—and if he had not, his discovery would have never been accepted in science. The distinction between both contexts is an abstraction and in many cases, both contexts are not disjunctive as in the case of Kekulé, but overlapping.

Critical Rationalism as described by Popper(1963) took the extreme position that the context of a discovery is completely irrelevant. Popper mainly understood science as an endeavour based upon trial and error—or in his words: conjecture and refutation. Although Popper's views have appeal to many working scientists (Godfrey-Smith, 2003), the extreme position held by Critical Rationalism has been critiqued. Most famously, Kuhn (1970) attacks Popper's position and holds a descriptive, mainly historical, view of science: that is Kuhn heavily emphasizes the way theories have actually been discovered. Moreover, Simon and co-authors (Simon, 1977; Langley et al., 1987) explore the potential of artificial intelligence for scientific discovery and show that it is possible to create and justify theories that are induced from data alone (for an introduction and discussion, see Aliseda, 2006 pp. 1–25).

For information systems design theories (ISDTs), the terms of *building* and *evaluating* have been established instead of those of building and testing (March & Smith, 1995). ISDTs provide a solution to a class of problems relevant for stakeholders (Walls et al., 1992; Venable, 2006; Baskerville et al., 2009; Baskerville & Pries-Heje, 2010). Although many publications in information systems design science research (ISDSR) focus on the justification (or *grounding*) of ISDTs or design artefacts (e.g., Fettke & Loos, 2003; Goldkuhl, 2004; Pfeiffer & Niehaves, 2005; Verschuren & Hartog, 2005; Frank, 2007; Siau & Rossi, 2007; Cleven et al., 2009; Tremblay et al., 2010) or on the whole process of ISDT or artefact development (e.g., Takeda et al., 1990; Nunamaker et al., 1991; Peffers et al., 2007; Kuechler & Vaishnavi, 2008), only a few publications highlight the problem of how to conceive of ISDTs, that is how to develop the idea of a problem solution (e.g., Vaishnavi & Kuechler, 2007; Gericke, 2009).[1] We argue that the choice of a mode of discovery has an important impact on the research outcome: That is, *abductively* discovered problem solutions are of an entirely different quality from *inductively* discovered ones. This paper aims at analysing these differences. A deeper understanding of these two types of design research, *inductive* and *abductive* design research, will contribute to a more precise discussion on ISDSR, including discussions on the methods for conducting ISDSR, particularly for evaluating research results.

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[1] It has to be noted, though, that the separation of *building* and *evaluating* has only recently been prominently criticised by Sein et al. (2011). Our contribution, however, has a different, more specific focus since it deals with forms of knowledge discovery in the first place and discusses its consequences in preceding and subsequent ISDSR phases. Although we explicitly reference the ISDSR phases as described by Peffers et al. (2007) our contribution will be transferable to the work of Sein et al. (2011). From a second perspective our work is more generic than that by Sein et al. (2011) since it applies not only to ISDSR that can be carried out with action research elements but also to e.g. highly innovative work for possible but not yet existing future worlds (Frank, 2009) – see our discussion of *validity* and *utility* in section 5.

The paper is structured as follows: First, we describe how discoveries are made in traditional science, distinguishing between *inductive* and *abductive discovery*. Second, we show how these two forms of discovery have been discussed in ISDSR literature. Third, we show two cases, one emphasizing abductive discovery, and the other emphasizing inductive discovery. The cases illustrate the importance of the forms of reasoning in ISDSR. Fourth is a critical reflection on ISDSR, with a discussion of the impact of a chosen mode of discovery on validity, utility, generality, and innovativeness of the problem solution. The paper closes with a summary.

2 Scientific Discoveries

Simon (1987 p. 4) distinguishes between data-driven discovery and theory-driven discovery. We argue that this distinction is very useful for this paper as well:

"Of course we cannot manufacture hypotheses out of whole cloth; there must be some starting point. But the starting point need not be a set of full-blown theories. Instead, it may be (and, I would argue, is) a relatively small set of primitive concepts that can be enlarged by recursive combinatorial processes to generate others. […] The information that provides the guidance, and leads the generation in relevant directions, can come from the data that we are seeking to explain with our new theories (data-driven discovery), or it can come from previously existing theories (theory-driven discovery), or it can come from some combination of these" (Simon, 1987 p. 4).

We take up Simon's differentiation between *data-driven discovery* and *theory-driven discovery*. However, we prefer to refer to the more fundamental forms of reasoning for discerning both types of discovery, as introduced by Peirce (1931–1958). Data-driven discovery mainly involves induction, whereas theory-informed discovery mainly involves abduction. We therefore use the terms *inductive* and *abductive discoveries* in the following. When describing the three modes of discovery in the following paragraphs, we emphasize the important questions of where the discovery comes from and the extent to which the discovering researcher is influenced by data, background knowledge and his or her own creativity?

Inductive discovery is data-driven. General knowledge is developed from observational data by inductive inference. At least since Hume (1989) we have known that inductive inference leads to uncertain knowledge. Simon (1987) emphasized inductive discovery and aimed to prove that it need not involve human creativity. He showed in two experiments that physical laws can be correctly developed by heuristic algorithms or mathematicians without any background knowledge. Simon interpreted the results of his experiments in two ways. First, data-driven discoveries are possible—that is discoveries without any background knowledge. Second, for people who are "skilled in the art", there are different approaches to correctly solve problems.

Abductive reasoning, in contrast, is emphasized by Popper, who fundamentally criticizes the idea that induction is the only source of discovery (1959 pp. 31–32; 1963 pp. 52–53):

"My view may be expressed by saying that every discovery contains 'an irrational element', or 'a creative intuition', in Bergson's sense. In a similar way Einstein speaks of the 'search for those highly universal laws ... from which a picture of the world can be obtained by pure deduction. There is no logical path', he says, 'leading to these … laws. They can only be reached by the logic of science intuition, based upon something like an intellectual love ('Einfühlung') of the objects of experience'" (Popper, 1963 p. 32).

Aliseda (2006 p. 46) understands abduction as inference from evidence and a body of background theories and knowledge. She identifies two triggers for abductive reasoning: a novelty, that is a completely new observation, and an anomaly, that is an observation which is inconsistent with the current body of back-ground-knowledge.

Like abduction, *deduction* involves (theoretical) background-knowledge but the two modes can be distinguished clearly from each other. A discovery can never result from the pure application of deductive reasoning. In deductive reasoning, a conclusion is logically derived from at least one premise, but it does not involve anything new (see e.g., Toulmin, 1958). As the term *discovery* has the notion of something *new* (in comparison to other terms, for instance to *observation*), pure deductive reasoning does not lead to discovery.

The question of forms of discovery in science is disputed. The positions range from those who argue that the inductive generation of knowledge is the only acceptable source of scientific knowledge to those who say that discoveries only result from an irrational element or a creative intuition. Place restrictions do not allow us to further discuss different standpoints. However, in this paper, we take an intermediate position, that was also held by Simon (1987). We argue that both inductive (data-driven) discovery and abductive forms of discovery are of value for science. From the three forms of reasoning (deduction, induction, and abduction), one can be excluded as a single source for a discovery: pure deduction does not generate new knowledge. However, background theories play an important role in abduction. It is evident that all discovery, be it a result of inductive or abductive reasoning, needs to be a part of the scientific process to be recognized as scientific (see e.g., Fischer & Gregor, 2011).

3 Inductive and Abductive Discovery in ISDSR Literature

We can distinguish inductive and abductive discovery for ISDTs as for all theory types. In this section, we show how these forms of discovery have been discussed in ISDSR. In defining ISDSR or ISDTs, many authors compare ISDSR to other research paradigms in IS, including *behavioral research (Hevner et al., 2004; March, 2006), that* aims to develop explanatory and/or predictive theories (Gregor, 2006; Gregor & Jones, 2007). In this context, ISDSR is often discussed in trems of three characteristics:

(1) validity and utility (Walls et al., 1992; March & Smith, 1995; Hevner et al., 2004; Winter, 2008; Baskerville et al., 2009)

(2) generality (Hevner et al., 2004; Frank, 2006; Winter, 2008; Baskerville et al., 2009), and

(3) innovativeness (March & Smith, 1995; Hevner et al., 2004; Frank, 2006; Baskerville et al., 2009).

In this section, we summarize prior research in ISDSR that focuses on inductive and abductive discovery of problem solutions and new knowledge. Congruent with the previous section, we emphasize authors' opinions on the primary origins of discoveries: data, background knowledge, or creativity.

Few authors in ISDSR discuss how to *inductively* develop ISDTs (for an exception, see Wania & Atwood, 2009). In general, induction is important for building ISDTs because it allows for generalizing singular observations. As Gregor (2006) points out, generalization is an essential characteristic of theory, independent of the theory type. For ISDSR, generalization is also important (Hevner et al., 2004; Venable, 2006; Gregor & Jones, 2007; Winter, 2008; Gregor, 2009; Baskerville & Pries-Heje; Aier & Fischer, 2011; Offermann et al., 2011).

Abductive discovery involves the creative use of background knowledge for discovering an innovative problem solution. The role of *background knowledge* for discovering ISDTs is discussed in the ISDSR literature. Walls et al. (1992) define kernel theories stemming from social or natural sciences as a core component of ISDT and Gregor and Jones (2007) use the term justificatory knowledge in a similar sense. Hevner et al. (2004) present an ISR framework and argue that ISR, including ISDSR, builds upon the IS knowledge base, which is not only composed of explanatory theories, but also of design knowledge, e.g., constructs, models, methods. Some authors argue that ISDTs have to be based on such background (Walls et al., 1992; Gregor, 2006; Gregor & Jones, 2007), other say merely that they are "nice to have" (Goldkuhl, 2004; Hevner et al., 2004; March, 2006; Venable, 2006; Kuechler & Vaishnavi, 2008; Fischer et al., 2010). For an overview see (Venable, 2006).

The role of *creativity* is relatively neglected in ISDSR. However, it is generally recognized that creativity plays a pivotal role for building theories (see also Mintzberg, 2005). Only a few publications explicitly deal with abductive reasoning as part of the notion of creativity. Takeda et al. (1990) and Kuechler and Vaishnavi (2008) propose a research process in which they explicitly mention the importance of abductive reasoning and creativity. Fischer and Gregor (2011) analyse the importance of creativity in other ISDSR processes. They moreover describe some cases of ISDSR in which creativity was important. These authors, however, do not propose how to creatively discover problem solutions. We found only two publications that explicitly deal with this issue (Vaishnavi & Kuechler, 2007; Gericke, 2009).

Vaishnavi and Kuechler (2007) describe different patterns which are useful for conducting ISDSR. In their patterns, they refer mainly to previous research in a variety of fields and show their applicability to ISDSR. One chapter in their book deals with creativity patterns, including a six stage inventive process developed in psychology, including a wild combination of ideas, idea generating by brainstorming and subsequent filtering, and the creation of conditions for stimulating creativity.

Gericke (2009) transfers problem solving patterns from engineering to ISDSR. Her contribution is based on the TRIZ problem solving patterns, developed in engineering (Altschuller & Shulyak, 2002; Altschuller, 2005; Altschuller, 2006; Orloff, 2006). The basic idea of TRIZ is that a pure trial-and-error method is inefficient in engineering. The developers of the TRIZ patterns therefore analysed a large number of innovative problem solutions and developed forty generic patterns for the creation of such solutions. Gericke not only verifies the patterns by Vaishnavi and Kuechler (2007) by mapping them to TRIZ patterns, but also develops new patterns, for instance idea tracking, multiple tasks, or provocation.

4 Information Systems Design Science Research Cases

In this section, we describe two examples for discoveries of ISDTs, both in the area of enterprise architecture management (EAM). The first case describes an inductive discovery of an ISDT; the second case gives an example of an abductive discovery of an ISDT. These cases provide appropriate ISDSR examples for critical reflection on the dimensions of *validity/utility*, *generality*, and *innovativeness* in section 5. We have chosen these particular examples as some of the authors had in-depth knowledge of the cases and the research processes involved beyond published accounts.

4.1 Inductive Discovery: The Case of Hafner

As an example of inductive discovery of a problem solution, we discuss the Ph.D. thesis by Hafner (2005), published in the German language. The main contribution of the thesis is summarized in the English language in a section of Hafner and Winter (2008).

Hafner develops a method for the management of application architecture, which is part of EAM. To this end, he takes case studies in three financial companies and documents their approaches to application architecture management. For structuring and mapping of the cases he defines a list of requirements and maps the respective activities of each case working towards these requirements. By induction, i.e. analysing the mappings of requirements and activities, Hafner finally develops a consolidated method which is drawn from the three cases. The method is comprised of the four activities of architecture planning, architecture development, architecture communication, and architecture lobbying. These activities are then described in further detail and the decisions as to why and how the individual activities were adopted from a particular case are substantiated. Hafner and Winter claim their method "to be universally valid over the focused domain. In particular, it [that is their method] is expected to be adoptable for big companies that are characterized by heterogeneously grown application landscapes. Identifying analogous structures and patterns by means of induction is an essential starting point for being accepted as universally valid" (Hafner & Winter, 2008 p. 8). Besides their method's *validity* the authors also assume its *utility,* since the foundational methods of the cases proved to be useful in its respective environments. However, their artefact's *generality* is limited to the analysed environments. Whether or not their method performs equally well in yet unknown environments is unknown. The artefact's *innovativeness* is, however, limited since similar solutions or solution components were already in place.

Hafner's approach also involves some creativity. Hafner consolidates the three specific solutions to one general problem solution; he thereby not only had to assure the internal consistency of his new solution, but also select the relevant building blocks from each of the solutions.

4.2 Abductive Discovery: The Case of Aier and Winter

As an example of the abductive discovery of a problem solution, we discuss the work of Aier and Winter (2009). The authors discuss the issue of business/IT alignment from an EAM perspective. Specifically they aim at sustainability of business/IT alignment, admitting that both business architecture and IT architecture are subject to independent evolutionary changes causing misalignment. Therefore the authors propose an additional virtual decoupling layer which exists only in architectural models and decouples changes in business architecture from IT architecture and vice versa.

Aier and Winter base their work on background knowledge of different levels of abstraction. The most abstract background knowledge is general systems theory. "Systems that intercept disturbances of the environment locally without distributing the disturbances to other parts of the system are called ultrastable systems (Ashby, 1981 p. 48). The interdependencies of system components can be reduced or intercepted by using multistage systems (Luhmann, 2002 p. 169). This interception of dependencies is also referred to as 'loose coupling' (Glassman, 1973; Weick, 1976; Luhmann, 2002 p. 171)" (Aier & Winter, 2009). Specifically the authors refer to the "containment" concept to support loose coupling. A containment serves as wrapper which again follows the principles of 'loose coupling' (Luhmann, 2002 p. 171). In their work Aier and Winter propose a virtual alignment layer which is comprised of enterprise services as such a containment.

Additionally the authors analyse other more concrete examples of containments as a basis for their artefact construction, i.e. the ANSI/X3/SPARC 1975 standard for databases also known as three-layer database architecture as well as markets and the role of standards in markets.

The *creative* aspect was a significant part of the research process as can be seen in the abstraction of business and IT architecture as decoupled layers and subsequently the identification and transfer of the abstract mechanisms described above to a completely new field, the design and modelling of organizations. Also the design of alignment artefacts (mainly enterprise service models) was a creative task which was, however, informed by existing theory. The artefact's *validity* and *utility* may be indicated by the fact that a number of large organizations apply such models successfully today for business/IT alignment. Their proposed artefact is rather *general* in its domain, the description stays abstract. Therefore different implementations can be observed in practice. Regarding the artefact's *innovativeness* it has to be recognized that the basic mechanisms of their artefact are not completely new—prior ideas are adapted to a new setting. However, in its area of application (business/IT alignment) the approach has been critically discussed by scientists and also often by practitioners, which may serve as an indicator of the level of novelty and surprise.

5 Critical Reflection

As we showed in section 3, ISDSR has three main characteristics: (1) validity and utility, (2) generality, and (3) innovativeness. In this section, we discuss the extent to which the two forms of discovery of ISDT are useful for conducting ISDSR research that has these characteristics.

The *validity and utility* of ISDTs must be shown, for inductively as well as for abductively gained ISDTs. By validity, we mean that the theory proposes a solution that works correctly; by utility, we mean in addition that the ISDT fulfils stakeholders' needs. Although, in practice, it is often timeconsuming to prove the validity of an ISDT, we argue that the utility evaluation is even more difficult as it concerns not only technical, but also socio-technical aspects. We therefore focus primarily on the utility evaluation of an ISDT in the following discussion.

As our case studies show, both forms of discovery allow for finding valid and useful solutions for relevant problems. The advantage of inductively gained solutions is that they have already been used in practice and have given first proofs of their utility. Goldkuhl and Cronholm (2003) however claim that there is still a need to prove the utility of inductively constructed theories. In contrast, abductively gained solutions have not been tested at all up to their discovery. In some cases, there may be some justification for the utility of the solution stemming from prior theory; however, such justification has two restrictions: first, in most cases it will be relatively limited and, second, it will refer to some of the design decisions only and not to all, at least in the case of complex solutions (see Gehlert et al., 2009). Therefore, such theories should be tested and evaluated. This is, however, not unproblematic as we show in the following.

Table 1 summarizes five different challenges related to the evaluation of the utility of ISDTs. These challenges are addressed in further detail below and are a starting point for further research in ISDSR.

No.	Problem
(1)	If the utility of a prototype is tested, the ISDT is not directly tested. A prototype is not deductively derived from an ISDT, but it extends it. It is unclear whether the characteristics of a particular ISDT or additional properties of its implementation are tested.
(2)	The performance of an artefact depends very much on its environment.
(3)	Different stakeholders perceive the utility of the same artefact in a different way. Therefore, utility is a multi-dimensional measure, with different dimensions for each stakeholder type.
(4)	Some ISDTs cannot be implemented as the researcher does not have access to an environment to implement it.
(5)	Some ISDTs cannot be implemented as an environment for implementing it does not yet exist.

Table 1: Problems related to evaluation of utility (for references, see the following paragraphs)

Problem (1) According to the interpretation by Fischer and Gregor (2011), the implementation of a prototype belongs to the phase of hypothesis generation; and the evaluation of the problem solution belongs to the phase of empirical hypothesis testing. However, both types of research process, the process in natural sciences and that in ISDSR, are less similar than it might seem at a first glance. In natural science, the object of research already exists; in design science, it has to be created. The design is mainly done by developing a prototype, as Peffers et al. (2007) as well as Kuechler and Vaisnavi (2008) describe it. This prototype development is however not purely deductive, but highly creative. In summary, in natural sciences, a hypothesis for testing is deductively derived from a proposed theory. In ISDSR, in contrast, theory testing is a two-step-process. A prototype is needed for hypothesis testing and this prototype extends the design theory. Strictly speaking, it is not the design theory that is tested, but the prototype. Further, it is not always clear whether the essential characteristics of the design theory or the additional requirements of a prototype are tested.

Problem (2) The performance of an artefact depends on the environment in which it operates (March & Smith, 1995). Therefore, it is difficult to make general propositions concerning the utility of a design theory, except perhaps for fairly tightly constrained technology-oriented artefacts.

Problem (3) Different stakeholders judge the utility of the same artefact in a different way (Aier et al., 2011). For instance, analytical information systems often depend on the data quality provided. Those stakeholders who have to assure a high quality of the data they enter into a system often complain about additional workload and do not profit from the system. In contrast, decision makers profit highly from analyses enabled by the system. It is obvious that both stakeholder types will judge the utility of that system in a different way. As Aier et al. point out, the views of different stakeholders should be considered separately.

Problem (4) Some design theories cannot be tested in a real-world environment as the researcher does not have access to it. For instance, for implementing a theory for designing the organization of a large-scale enterprise, the researcher would have to have access to a CEO of a large-scale enterprise who is willing to try out the theory—this is unlikely.

Problem (5) Finally, as Frank (2009) points out, ISDSR aims to develop future worlds. In order to be innovative, ISDSR sometimes has to develop solutions for upcoming problems. Assume, for instance, a variety of web services will be available in the future, but do not exist yet. An IS design science researcher can then develop an innovative ISDT for managing these web services. However, the utility of such a solution cannot be proven in a real environment, yet, as a high number of web services does not exist.

We conclude that the utility of ISDTs is difficult to evaluate in many cases, and it is likely to be even more difficult in cases of abductive discovery compared with inductive discovery.

Generality is an important characteristic of theories, including ISDTs (Gregor, 2006). However, as Lee and Baskerville (2003) show, generalizability is a challenge in ISR. Moreover, it is difficult to prove the generality of an ISDT as the performance of an artefact highly depends upon its environment (March & Smith, 1995). For our discussion of the two means of discovery, inductive and abductive discovery, we draw on our discussion of utility above. Both, inductively and abductively discovered ISDTs can claim to be useful for a narrow or wide area of application.[2] The challenge, however, is to provide good evidence for such claims. For inductively gained ISDTs, generality can be proven more easily as the problem solution has already been applied in a variety of situations. For abductively gained ISDTs, generality needs to be proven by evaluation—with the problems discussed above (see table 1).

The *innovativeness* of inductively gained solutions is in general comparatively low. Inductively gained solutions uncover problem solutions applied in practice and consolidate them; they represent good practice. If only good practices are generalised by the researcher, he or she does not develop new ideas. Inductively gained design theories are valuable, however, although their degree of innovativeness is relatively small, as the example of Hafner (2005) shows.

Abductively gained ISDTs, in contrast, are the result of a creative reasoning of the researcher. Evidently, the chances for a highly innovative ISDT are higher. If innovative artefacts are aimed at, abductive reasoning is a necessary condition.

In *conclusion*, our discussion shows that a pivotal challenge of ISDSR is the evaluation of ISDTs (see also Frank, 2006; Frank, 2009). In table 1, some particular problems related to the evaluation of ISDTs are summarized. These problems make it difficult to establish the utility and generality of ISDTs that have been developed abductively; thus lending support for the inductive discovery of ISDTs. The requirement of innovativeness, however, is an argument for the abductive discovery of ISDTs. Abductively discovered ISDTs more significantly involve the researcher's creativity.

Besides the different degrees of innovativeness, both approaches also differ on a methodological level. Table 2 summarizes these differences.

The trade-off seems to force the IS design researcher to decide between creatively developed artefacts with a high degree of innovativeness whose utility and generality can be established with difficulty or to inductively develop ISDTs by observing and consolidating good practices without developing anything significantly new. However, as Frank (2006) also shows, the problem is also based on the implicit assumptions of ISDSR trying to implement traditional research processes, for instance that of

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[2] Aside from means of discovery it has to be noted, though, that there is a strong relationship between utility and generality: the more specific an ISDT is, the more useful it will be for the respective user of this ISDT because less adaptation efforts are needed for her specific situation. From a more holistic community perspective, however, a more generalized artefact may provide a high utility.

Critical Rationalism (also see Fischer & Gregor, 2011). Some of the problems listed in table 1, for instance problems (4) and (5), can be weakened if a different view of evaluation is applied. A third way could therefore be to discuss the underlying assumptions of our understandings of ISDSR processes more intensively (Frank, 2006).

Research Phase (Peffers et al., 2007)	**Abductive Design Science Research**	**Inductive Design Science Research**
Identify need and objectives of a solution	The need for the problem solution can be empirically identified. If the solution is meant to solve a future problem, researchers need to argue why there will be a need for the solution in future.	The need for the solution is most often obvious as it is applied in practice for a specific need. The researcher's analysis contributes to a clarified understanding of the problem.
Design and develop a solution	Researchers creatively develop a new idea that has not been applied in practice nor described in research, yet. Approaches of action research or even action design research may be appropriate in order to shape a creative and/or abstract idea in an organizational context (Sein et al., 2011).	Researchers observe how a problem is solved in practice. Problem solutions applied in practice should have a certain maturity. However, they have not yet rigorously been analysed in research. Therefore design research approaches as describes by Peffers et al. (2007) seem appropriate. Action design research might be helpful for an abstraction of further context factors.
Demonstrate and evaluate the solution	For evaluation, the artefact should be prototypically implemented and evaluated in the problem context. If the artefact is meant to solve a future problem that is not existent at the moment, good reasons for its utility should be given.	The utility of the problem solution is shown by its successful application in the observed cases. Additions by the researcher need to be evaluated. In order to further increase the reliability of the artefact, it can be evaluated in further contexts.

Table 2: Summary of characteristics of abductive and inductive ISDSR

6 Summary

Theories can be discovered inductively or abductively. Both forms of discovery have been discussed in the philosophy of science. Some authors emphasize the importance of inductive discovery (e.g., Simon, 1987) whilst others emphasize that of abduction, e.g., Critical Rationalism (Popper, 1963). As our literature analysis and our two case studies show, both forms of discovery are not only important for the discovery of theories in natural sciences, but also for that of Information Systems design theories. Both forms of discovery, as we show, have strengths and weaknesses. The strength of an inductive discovery of ISDTs is that its utility and generality can be proven more easily than that of abductive discoveries. Accordingly, the problems related to the evaluation of ISDTs are the main weaknesses of abductive discoveries. However, the main weakness of inductively discovered design theories is their small degree of innovativeness; accordingly, the higher innovativeness of abductively discovered design theories is the main strength of abductively discovered design theories. However, from a long-term perspective induction may also indirectly foster innovation. Generic artefacts can be derived from specific artefacts by induction, which allows for understanding and evaluating artefacts at a higher level of generality. Generalized artefacts will more likely be transferred to different or even entirely new problem classes which may result in an innovative, abductively derived contribution to the ISDSR body of knowledge.

In future research, we suggest discussing the issues related to the evaluation of abductively discovered ISDTs more intensively. In addition to a binary decision between inductive discoveries of ISDTs with a small degree of innovation and abductive discoveries of ISDTs with challenges for proving their utility, a third way might be to discuss models of research that differ more fundamentally from those applied by natural sciences (see the exhaustive discussion by Frank, 2006).

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