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A Good Beginning Makes a Good Ending: Incipient Sources of Knowledge in Design Science Research

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Completed Research Paper

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Abstract

Design science research (DSR) focuses on providing innovative solution knowledge to complex and hitherto unsolved problems. Identifying both relevant problems and unique solutions require in-depth understanding of the problem domain and potential solution technologies. Incipient sources of knowledge provide the means to find such important design problems, evaluate their relevance, and create innovative, tentative designs to tackle these problems. However, current DSR literature provides little guidance for identification, selection, and consumption of incipient knowledge. In this paper, we, therefore, set out to identify and analyze the incipient sources of knowledge in DSR with the help of a comprehensive literature review. Our work could thereby serve as a starting point for further exploration of the nature of design science knowledge and help to create novel guidelines and research processes that guide the selection and utilization of incipient DSR knowledge sources.

Keywords: Design science research, incipient knowledge, knowledge consumption, knowledge sources, DSR

Introduction

The design science research (DSR) paradigm offers a unique perspective in information systems (IS) research that is focused on providing innovative solution knowledge to complex and hitherto unsolved problems (Gregor 2006; Iivari 2015; Peffers et al. 2007). DSR addresses these problems through the development, implementation, and evaluation of generalizable technology solutions (Hevner et al. 2004; March and Smith 1995; Sein et al. 2011; Simon 1996). Following the paradigm, past DSR endeavors have led to innovative answers to important issues in fields such as healthcare (Almufareh et al. 2018; Alrige and Chatterjee 2018; Nguyen et al. 2018), science (Larsen and Bong 2016; Sturm and Sunyaev 2017; Sturm and Sunyaev 2019), or management (Blaschke et al. 2017; Dellermann et al. 2017). Conducting DSR can essentially be described as a search process for finding effective solutions to relevant problems (Hevner et al. 2004). In this process, design researchers use available means to get to the desired ends in compliance with the contextual rules (Gregor and Hevner 2013; Simon 1996). Within this high-level description of DSR, two prevailing challenges in design research are implicated.

First, DSR is a goal-oriented research paradigm that typically involves pragmatic research activities, which center around the construction and evaluation of information technology (IT) artifacts in order to provide relevant contributions to a specific application domain (Hevner 2007). Due to this pragmatism, design researchers often face the challenge of differentiating their work from routine design and system building (Davis 2005; Hevner et al. 2004). Building an IT system is usually not a relevant scientific contribution, owing to a lack of novel theoretical insights since it involves simply "doing something that everyone knows can be done and at least conceptually how to do it" (Davis 2005, p. 18). In order to create valuable additions to the knowledge base, design researchers need to address "important unsolved problems in unique or innovative ways" (Hevner 2007, p. 89). Identifying both relevant problems and unique solutions requires an in-depth understanding of the problem domain and potential solution technologies (Vaishnavi and Kuechler 2004; Venable 2006a). This understanding is drawn from a large knowledge base (e.g., scientific theories, models, methods, instantiations) and the application environment (e.g., people, organizations, and technologies) (Hevner 2007; Hevner et al. 2004). Furthermore, in order to understand the expected outcome of a DSR project, it is necessary to first assess the type of knowledge contribution being made in regard to the existing knowledge base (Vaishnavi and Kuechler 2004). Hence, while later design activities are often informed by knowledge generated by the design process itself (Gregor and Hevner 2013; Hevner 2007; Peffers et al. 2007; Sonnenberg and vom Brocke 2012), incipient, extant sources of knowledge that inform the early stages of DSR endeavors often provide the foundational means to find important design problems, evaluate their relevance, and create innovative, tentative designs to tackle these problems (Peffers et al. 2007; Sonnenberg and vom Brocke 2012).

Second, on account of DSR referring to a broader research paradigm (Hevner et al. 2004; Iivari 2015) and not to a specific research approach, numerous guidelines exist that provide the DSR community with a rich methodological knowledge base, focusing either more on design theory (Gregor and Jones 2007; Mandviwalla 2015; Markus et al. 2002; Pries-Heje and Baskerville 2008; Walls et al. 1992) or emphasize a more pragmatic construction-driven DSR perspective (Hevner 2007; Hevner et al. 2004; March and Smith 1995; Nunamaker et al. 1990; Peffers et al. 2007). On the one hand, this provides a level of flexibility and creativity that is often required when searching for innovative solutions to wicked problems (Gregor and Hevner 2013). On the other hand, the increasing breadth of DSR methodologies can be overwhelming for novice researchers attempting to conduct a design research project, leading to the risk of creating weak or irrelevant research contributions (Sonnenberg and vom Brocke 2012; Vaishnavi and Kuechler 2004). Furthermore, despite the aforementioned importance of incipient knowledge sources, current DSR literature is still vague in terms of incipient knowledge sources with little guidance for identification, selection, and consumption of incipient knowledge. However, an initial lack of understanding of the problem domain and solution technologies could have far-reaching consequences for the entire research project, leading to either less interesting or entirely irrelevant research contributions (Hevner 2007; Sonnenberg and vom Brocke 2012).

To tackle this prevailing issue in DSR, novel methodological contributions are required. However, to this end, we first need a better understanding of the nature of incipient knowledge in DSR, which, in particular, requires an understanding of the sources of incipient knowledge used in current DSR research. In this paper, we, therefore, as a first step, address the following research question: *What are the incipient sources of knowledge in current design science research?*

To answer our research question, we reviewed 191 DSR projects published in the International Conference on Design Science Research in Information Systems and Technology (DESRIST) as well as the AIS senior scholar basket journals reaching back seven years. Based on this literature sample, we analyzed and classified the incipient sources of DSR knowledge that informed the initial artifact design cycles of the described DSR projects, including all preceding activities (e.g., problem identification). In doing so, in this paper we present a comprehensive overview of the incipient sources of knowledge, shed light on how they are applied and investigate what we may learn from this process. We further offer insights into the current state of DSR and reflecting the practice of successful DSR projects. This paper thereby contributes to the DSR literature stream by providing insights into the DSR community and thereby pave the way for novel methodological contributions. Future research may utilize our work as a starting point for further explorations of the nature of design science knowledge, for instance by incorporating additional phases of DSR. Furthermore, our results could help to create methodological contributions in the DSR community in the form of novel guidelines or research processes that, in particular guide the selection of appropriate incipient knowledge sources.

The remainder of this paper proceeds as follows. In the next section, we provide a comprehensive overview of prior literature on incipient knowledge, the classification of its sources and its consumption. Section 3 explains the applied research approach, followed by the presentation and discussion of the results of our literature review in section 4. Finally, in section 5, we conclude the paper by summarizing the work.

Incipient Knowledge and Knowledge Consumption in DSR

DSR can be broadly defined as "knowing through making" (Purao 2002), whereas *making* refers to the construction and evaluation of IT artifacts. An IT artifact is an object made by human beings with material and informative properties that has a material existence or can be materialized as an artificial object (e.g., models and instantiations) or a process (e.g., methods and software) (Goldkuhl 2002; Gregor and Hevner 2013). IT artifacts can further be grouped into four categories: constructs, models, methods, and instantiations (e.g., software products or implemented processes) (Hevner et al. 2004; March and Smith 1995; Niederman and March 2012). Through construction and evaluation of IT artifacts, design researchers gain a better understanding of underlying problems and their potential solutions. These insights can eventually lead to the derivation of valuable design knowledge contributions, such as situated implementations of artifacts and (nascent) design theory (Gregor and Hevner 2013; Nunamaker et al. 1990). Given the central role of artifacts in DSR, a well-grounded argument for the design of an artifact is a key factor for rigorous design research (Hevner 2007; Hevner et al. 2004; Iivari 2007). This implies that in DSR "knowing through making" is to be accompanied by "making through knowing". Owen (1997) illustrates this circular relationship in his general model for generating and accumulating knowledge (see Figure 1). In the model, knowledge is used to create works and the evaluation of these works, in turn, generates new knowledge (Owen 1997). To investigate our research question, in this paper we focus on the first "making through knowing" phase of DSR projects. On account of DSR being referred to as research paradigm (Hevner et al. 2004) or a research orientation (Iivari 2015), it subsumes numerous research methods, processes, and strategies (e.g., Gregg et al. 2001; Hevner et al. 2004; March and Smith 1995; Nunamaker et al. 1990; Peffers et al. 2007; Purao 2002). Accordingly, there are also diverging positions on and approaches for incorporating external knowledge during the early phases of DSR projects. In the following, we provide an overview of the different perspectives from extant literature.

Peffers et al. (2007) describe artifact development as search process "that draws from existing theories and knowledge to come up with a solution to a defined problem" (p. 49). The corresponding development methodology (i.e., DSRM; Design Science Research Methodology) consists of six activities that are chained together with an iterative design process cycle. Within each activity, different knowledge requirements are identified. Activity 1 (i.e., problem identification and motivation) requires knowledge that informs the state of the researched problem and its relevance. Defining objectives for a potential problem solution (activity 2) involves knowledge about the problem state as well as awareness of solutions to related problems. Activity 3 (i.e., design and development) requires theory input that may be applied in the development of a potential solution artifact. The final two activities involve knowledge about metrics and analysis approaches for artifact evaluation (activity 5: evaluation) and knowledge about the disciplinary culture of the research community to which the resulting design knowledge is to be communicated (activity 6: communication).

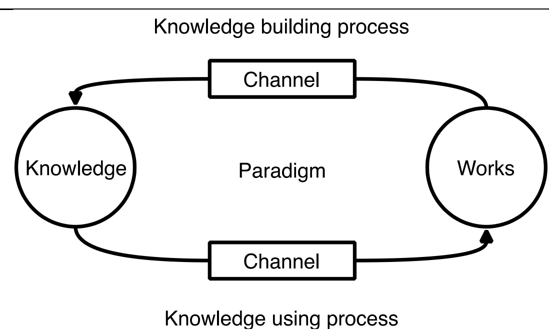

Figure 1: A General Model for Generating and Accumulating Knowledge (Owen 1997)

In more general terms, Nunamaker et al. (1990) present an IS (design) research process that draws on the body of knowledge consisting of extant knowledge about the research domain and research methodologies. The proposed research process comprises "understanding the research domains, asking meaningful research questions, and applying valid research methodologies to address the questions." (Nunamaker et al. 1990, p. 91). Nunamaker et al. (1990) emphasize the necessity of a thorough and complete understanding of the research domain to enable researchers to ask the right research questions and come up with meaningful hypotheses. Furthermore, multiple disciplines should be reviewed to identify (potential) approaches and ideas that might inform an artifact's design.

Gregor and Jones (2007) include justificatory, explanatory knowledge that creates the connection between all other aspects of design theory (e.g., goals, processes, and materials). Gregor and Jones (2007) suggest that researchers should explore extant knowledge on the design of artifacts that serve a purpose similar to that of the researched artifact. In particular, for the development of cumulative design theory, Gregor and Jones (2007) recommend to identify the purpose and scope of design theory first and then "build on as much relevant prior work as possible" (p. 331).

Purao (2002) notes that the process of identifying and realizing design research opportunities requires a comprehensive understanding of appropriate technologies and related design research. Following Purao (2002), a design process is bounded by extant theory and prior design research (e.g., knowledge of principles underlying cognitive science, organizational behavior, and management practices), which allow to frame the phenomena under scrutiny (i.e., discovery, scoping, and articulation of the potential design research goal) and provide novel design variants and perspectives for the artifact to be developed. Extant knowledge is consciously or subconsciously applied in an iterative design process that identifies feasible solutions from the potential solution space to address the researched phenomena (Purao 2002).

Gregor and Hevner (2013) suggest that DSR publications require a literature review section presenting an overview of the descriptive and prescriptive knowledge (e.g., theory, prior prescriptive knowledge, or existing artifacts) relevant for the problem of interest. This review should be comprehensive enough to ensure the novelty of the developed artifact by covering any relevant knowledge that addresses problems similar to the one of interest. Gregor and Hevner (2013) emphasize the importance of positioning "the paper against [...] the existing state of knowledge for the problem area (if any)" (p. 351).

Hevner et al. (2004) provide two reasons for reviewing and incorporating extant knowledge in DSR, namely relevance and rigor. This idea is further detailed and refined in Hevner (2007) by the introduction of a rigor and a relevance cycle that create links between primary DSR activities (i.e., building and evaluation), the application environment, and knowledge base. As depicted in Figure 2, the relevance cycle connects design activities with the relevant application domain (i.e., the contextual environment). The application domain consists of three main elements–people, organizational systems, and technical systems–that interact with each other to reach a common goal (Hevner et al. 2004). Gaining knowledge of the application domain is described as the starting point for DSR (Hevner 2007). The design researcher has to identify one or more relevant opportunities and problems to be addressed in the research project (i.e., requirements of the project) that will enable improvement to practice. The researcher's knowledge about the application domain also serves as input for evaluation criteria against which the derived design knowledge needs to be tested (e.g., to demonstrate that the design artifact improves the contextual environment). The design project's grounding in and contribution to the scientific knowledge base is represented by the rigor cycle. Hevner et al. (2004) emphasize that researchers need to rigorously investigate the extant knowledge base to ensure that the results are valuable research contributions and not merely routine design (i.e., application of known solutions to known problems). Potential sources for extant knowledge are kernel theories, engineering methods, state-of-the-art in the application domain (i.e., experience and expertise), and existing artifacts found in the application domain. However, while kernel theories from natural and behavioral sciences are often asserted to be important knowledge sources in DSR (Goldkuhl 2004; Nunamaker et al. 1990; Orlikowski and Iacono 2001; Simon 1996; Venable 2006b; Walls et al. 2004), a strong theoretical grounding of an artifact's design is not the only indicator for rigorous DSR (Hevner 2007; Iivari 2007). Hevner (2007) also emphasizes the importance of sources of creative insights (e.g., Csikszentmihalyi 2013) for producing true innovations in DSR projects for which existing kernel theory might not always be applicable. Knowledge from both rigor and relevance cycle serves as input for the design cycle, which iterates between artifact construction and evaluation, and thereby generates the actual design knowledge output of the research project. Hevner (2007) underlines that the design cycle is informed by the other two cycles but, once informed, "relative independent during the actual execution of the research" (p. 91), which provides creative freedom for developing novel and innovative design solutions.

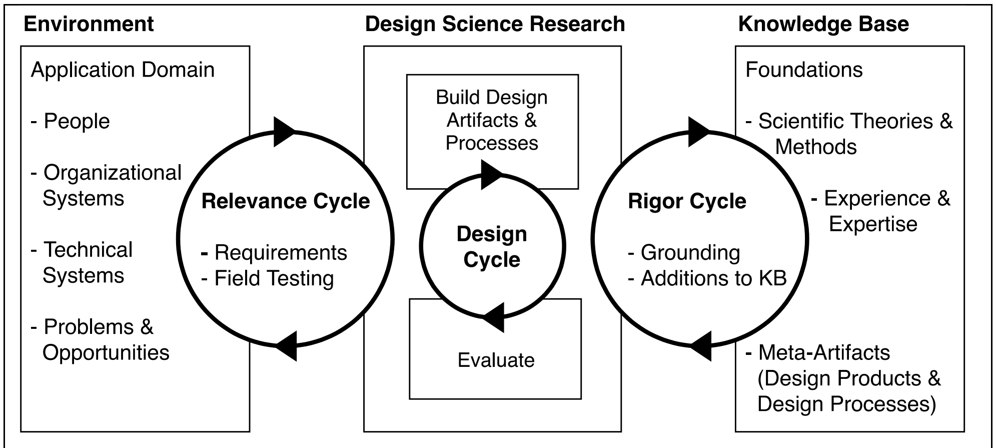

Figure 2: Design Science Research Cycles (Hevner 2007)

Sonnenberg and vom Brocke (2012) propose in their DSR evaluation framework an investigation of the problem space related to the phenomenon of interest through evaluation of an initial problem statement. To this end, several evaluation approaches are suggested, like literature reviews, reviews of practitioner initiatives, expert interviews, and focus groups. The main purpose of these early evaluation efforts is to ensure the relevance of the investigated DSR problem. The problem's relevance refers to the practical impact its solution could have and its potential for providing a valuable addition to the knowledge base, which corresponds to the concepts of relevance and rigor proposed in Hevner et al. (2004) and Hevner (2007). The first evaluation of the problem statement, called *Eval1*, is, therefore, in part congruent with Hevner's relevance and rigor cycles and underlines the importance of incipient knowledge sources in DSR.

In summary, the design process itself is seen as (partially) independent from existing knowledge, which provides the necessary freedom to create innovative solutions for wicked problems for which no prior solution knowledge was readily available (Hevner et al. 2004; Weber 1987). On the other hand, there is general consent that DSR requires extant knowledge input for identifying and understanding the researched phenomena, to increase the rigor of the design research process, and to ensure relevance, novelty, utility of the developed solution.

Classifying Extant Knowledge in DSR

Knowledge can be defined as the sum of what is known, that is the body of truth, information, and principles acquired by humankind (Merriam-Webster 2019). Since the all-encompassing knowledge space is so vast and continuously expanding, structuring knowledge into classes is essential for its understanding and, in particular, its advancement (Dalkir 2005; Kwasnik 1999). Such knowledge classifications define a structure and boundaries of knowledge (Kwasnik 1999; Olson 1998). Historically, there have been many efforts to classify knowledge, with different disciplines focusing on different dimensions (Dalkir 2005). This has resulted in many classification schemes, taxonomies, and distinctions grounded in science, religion, or philosophy (Dalkir 2005; Gregor and Hevner 2013; Parry 2014). As discussed in the previous section, in DSR, new design insights and discoveries will not become part of the knowledge base, unless they are related to and integrated with existing knowledge (e.g., via the rigor cycle). Understanding and differentiating between different forms of knowledge is, therefore, an essential prerequisite for creating a valuable knowledge contribution. The concept of a knowledge base already poses one potential classification scheme. Many disciplines, over time, establish a coherent body of knowledge (BoK) that codifies the knowledge base accumulated within the discipline (Iivari et al. 2004). In the DSR context, BoK describes the knowledge base that surrounds a specific phenomenon, which may be natural, artificial, social, or human (Gregor and Hevner 2013). Such a BoK provides the basis for the design of practical and useful artifacts (Gregor and Hevner 2013) and is the basis for a DSR project's justificatory knowledge. Justificatory knowledge explains why an artifact is constructed in a certain way, why it works, and how a newly built design theory differs from existing theory (Gregor and Jones 2007; Sonnenberg and vom Brocke 2012). Justificatory knowledge may comprise any knowledge that informs design research (Gregor and Hevner 2013), including informal knowledge from the field and the experience of practitioners as well as natural science theories, social science theories, other design theories, practitioner-in-use theories, or evidence-based justificatory knowledge (Gregor and Hevner 2013; Gregor and Jones 2007). Justificatory knowledge can be of a descriptive or predictive nature (Gregor and Hevner 2013; Sonnenberg and vom Brocke 2012). Prescriptive knowledge relates to "artifacts designed by humans to improve the natural world" (Gregor and Hevner 2013, p. A3) and, thus, can be directly attributed to the sciences of the artificial (Simon 1996). Prescriptive knowledge, which may be an input for and an outcome of DSR, can be classified into four types: constructs (e.g., vocabulary, symbols), models (e.g., abstractions, representations), methods (e.g., algorithms, practices), and instantiations (e.g., implemented, prototype systems) (Hevner et al. 2004; March and Smith 1995). Descriptive knowledge in DSR comprises descriptions of natural, artificial, and human-related phenomena (e.g., observations, classifications, measurements) and sense-making relationships among the phenomena (e.g., natural laws, principles, regularities, patterns, and theories) (Gregor and Hevner 2013). The latter is often also referred to as kernel theory. The term kernel theory was coined by Walls et al. (1992) and describes theories that inform DSR activities and originated in disciplines outside of IS (e.g., natural science, social sciences, or mathematics). Since then, the meaning of the term has become ambiguous (Gregor and Hevner 2013). Gregor and Hevner (2013), for instance, describe the function of kernel theories in DSR as (partially) explanation for why a particular design works. Kuechler and Vaishnavi (2008) describe the function of kernel theory to potentially inform both the sought-after effect of an artifact (i.e., its goal) and the means to reach this effect. As a component of IS design theory, Walls et al. (1992) incorporates extant kernel theories originated from natural or social science as a means to determine meta-requirements for design artefacts and to govern the design process. Despite its ambiguous use, kernel theory constitutes an important knowledge type in DSR, along with knowledge about the phenomenon, constructs, models, methods, and instantiations.

Another classification scheme, which is commonly used in the field of knowledge management, is the distinction between tacit and explicit knowledge (e.g., Brown and Duguid 1991; Bukowitz and Williams 2009; Cook and Brown 1999; Dalkir 2005). *Explicit knowledge* refers to knowledge that is formalized and codified (Brown and Duguid 1998). Knowledge of this type has been captured in a tangible form (e.g., text, audio, images), which makes its identification, storage, and retrieval relatively straightforward (Dalkir 2005; Wellman 2009). The *tacit knowledge* type, on the other hand, refers to knowledge that is difficult to articulate, define, and capture (Dalkir 2005; Polanyi 1966). It is hard to communicate, as it is largely based on expertise, rooted in action, commitment, and involvement (Nonaka 1994), and usually exists only in a person's mind (Brown and Duguid 1998). This makes tacit knowledge often personal in nature and depended on a specific context (Dalkir 2005). Tacit knowledge comprises, for instance, skills, capabilities, values, attitudes, cultural beliefs, and mental models (Botha et al. 2008). While being difficult to capture, tacit knowledge is nonetheless considered highly valuable due to its complex and innovative nature (e.g., Brown and Duguid 1991; Bukowitz and Williams 2009; Wellman 2009), which makes it a valuable source of knowledge when investigating phenomena in DSR involving human stakeholders. However, due to the implicit nature of tacit knowledge, design researchers can often only partially access and explicate the tacit knowledge base inside, for example, an organization in which the phenomenon of interest is examined (Maass and Janzen 2012).

Sources of DSR Knowledge

Knowledge consumed in DSR can originate from a wide variety of sources (Vaishnavi and Kuechler 2004) and, similar to the classification of DSR knowledge types, different perspectives can be used to differentiate between these sources. In the following, three different perspectives are described, namely the design perspective, methodological perspective, and disciplinary perspective.

The first distinction of DSR knowledge sources can be made based on whether they provide knowledge that informs a DSR problem or its (potential) solutions. In order to produce a valuable scientific contribution, design researchers have to create original knowledge that addresses a previously unsolved and relevant problem (Hevner et al. 2004). DSR in the IS context can, therefore, be interpreted as a mapping process between contextual problems and appropriate solution technologies (Venable 2006a). As discussed above, both sides of this mapping process need to be investigated in order to ensure rigor and relevance of the design process and its outcomes (Gregor and Hevner 2013). This means that DSR requires knowledge input from two sources, the application domain in which the problem of interest resides (i.e., the problem space) and the solution domain that provides technical and organizational knowledge, which informs the design of a potential solution to the problem (i.e., the solution space) (Hevner et al. 2004). The *problem space* comprises a "researcher's understanding of the problem(s) being addressed by a proposed solution technology, specified and placed in the context by relationships with other problems and problem aspects" (Venable 2006a, p. 185). The problem space essentially describes a context or environment in which the phenomena of interest exists (Simon 1996) along with contextual problems and opportunities created by interactions between individuals, organizations, and technologies (present and/or planned) (Hevner et al. 2004; Kuechler and Vaishnavi 2008; Silver et al. 1995). Depending on the researched context, the problem space may encompass knowledge from one reference discipline or different allied disciplines (Vaishnavi and Kuechler 2004). An in-depth understanding of the problem space helps researchers to design effective artifacts and to clearly demonstrate their contribution to the targeted context by solving hitherto unsolved, important issues (Hevner et al. 2004). The *solution space* holds the concepts that embody the solution technology (Venable 2006a). After becoming aware of the problem of interest through the exploration of the problem space, it is important to search prior research on related issues to identify a potential solution or parts thereof (Kuechler and Vaishnavi 2008). The solution space may provide theories, frameworks, instruments, constructs, models, methods, and instantiations that inform the design of a feasible solution for the problem of interest (Hevner et al. 2004). Similar to the problem space, the solution space is not bound to knowledge originated from a single discipline but may be composed of insights from multiple disciplines (Vaishnavi and Kuechler 2004). While one sign of rigor in DSR is the appropriate application of input provided by the solution space (Hevner et al. 2004), the solution space does not necessarily have to provide suitable knowledge for a particular design problem (Venable 2006a). Even though "everything is made of something else or builds on some previous idea" (Gregor and Hevner 2013, p. 344), innovative solutions often require knowledge that is either incomplete or yet nonexistent (Markus et al. 2002; Venable 2006a). Nonetheless, design researchers should make an adequate attempt to identify a (potential) solution space that might inform their design activities and allow to frame the research contributions (Vaishnavi and Kuechler 2004).

As has been pointed out earlier, DSR is an interdisciplinary research paradigm. This is certainly true for DSR in the IS context, due to IS being an interface discipline between many science branches (i.e., natural science, social science, applied science, and formal science) (Bernroider et al. 2013). Extant literature often suggests that design researchers should consider multiple research domains as well as practice to identify (potential) approaches and ideas that might inform the problem understanding and artifact design (e.g., Nunamaker et al. 1990; Vaishnavi and Kuechler 2004). Hence, a further classification criterion for DSR knowledge sources is the origin of knowledge in terms of its affiliation with a domain's body of knowledge. That is, design knowledge may either originate from the domain where the phenomenon of interest originates (i.e., intradomain knowledge) or from reference or allied domains that provide knowledge that can be transferred into the researcher's field (i.e., interdomain knowledge).

The method by which knowledge is acquired can also be understood as a knowledge source (Helmstadter 1970), which offers another classification angle. In DSR, numerous approaches are used for acquiring knowledge, besides constructing and learning from artifacts. Such approaches include, for example, reviews of extant literature, practitioner initiatives, and existing artifacts as well as case studies, expert interviews, focus groups, workshops, observations, and surveys (Sonnenberg and vom Brocke 2012; Venable et al. 2016). On a more general level, Helmstadter (1970) provides a classification scheme for knowing. The scheme identifies, in addition to scientific methods, five sources of knowledge, as summarized in Table 1: tenacity, intuition, authority, rationalism, and empiricism. Of lesser importance today is the method of *tenacity*, which is based on superstition and tradition (Helmstadter 1970). Based on tenacity, people may believe that something is true just because an earlier impression has evolved into an opinion and eventually was accepted as fact due to habit and without actual evidence. As a source of knowledge, tenacity is of lesser value, as it arises from highly subjective impressions and is, therefore, prone to produce conflicting viewpoints on the same truth. The method of *intuition* refers to facts that are perceived as self-evident. This source of knowledge is largely influenced by feelings and hunches (Helmstadter 1970). Seemingly obvious truths are held up, even though they are not directly based on collected evidence. When knowledge is acquired from an expert or respected source in a particular subject area, the method can be referred to as *authority*. Due to the constantly growing availability of information, consulting specialized knowledge sources (e.g., domain experts) have become a necessity for gaining in-depth knowledge on a particular subject area or phenomenon. Helmstadter (1970) differentiates between authorities whose decree has to be accepted as facts (e.g., churches or governments) and experts whose advice may be questioned or challenged. In DSR, the inclusion of expert views like, for instance, from domain or organization experts is a common practice (Hevner et al. 2004; Venable et al. 2016). When applying the *rationalistic* method, knowledge is derived through reasoning. The knowledge seeker makes logical conclusions based on the given truths. The logical shift from truth to conclusion often requires making assumptions, which may or may not be based on a person's experience. This makes the rationalistic method less reliable when it comes to completely new areas of knowledge, where there is a lack of experience to draw from (Carson 2004). There could be numerous hidden assumptions that would need to be made, in order to come up with a logical conclusion. Helmstadter (1970), therefore, dissuades from using reasoning as a method for scientific theorizing about untested innovations. This is in line with DSR's most fundamental requirement, which emphasizes the necessity of artifact evaluation in order to draw reliable design knowledge conclusions (Gregor and Hevner 2013; Hevner et al. 2004). The *empirical* method of knowing describes an approach that accepts knowledge as statement of truth if it concurs with a person's experience or observations. In case of disagreement with experience or observations, a potential statement of truth is rejected as knowledge. Personal experience is limited, selective (e.g., tendency to forget statements we disagree with), and may interfere with a knowledge seeker's objectivity during observations (Carson 2004). While "no scientist today can afford to rely alone on his impressionistic judgements to arrive at facts or truths or knowledge" (Helmstadter 1970, p. 14), it can be a valuable incipient source for design knowledge that helps to understand the phenomena of interest and potential solution technologies (Hevner 2007; Kuechler and Vaishnavi 2008).

Table 1: Methods of knowing, adapted from Helmstadter (1970)

Method	Definition	Source
Tenacity	A method of knowing based largely on habit or superstition. Knowledge is acquired based on superstition or habit, leasing us to continue believing something we have always believed.	Helmstadter (1970)
Intuition	A method of knowing based largely on individuals' hunch or feeling that something is correct. Knowledge is acquired without any reasoning or interfering.	Helmstadter (1970)
Authority	A method of knowing accepted as fact because it was stated by an expert or respected source in a particular subject area. Knowledge is acquired from highly respected sources.	Helmstadter (1970)
Rationalism	A method of knowing that requires the use of reasoning and logic. Knowledge is acquired through reasoning.	Helmstadter (1970) Carson (2004)
Empiricism	A method of knowing based on one's experiences or observations. Knowledge is acquired through personal experience.	Helmstadter (1970) Carson (2004)
Scientific method	Knowledge is acquired by testing ideas and beliefs according to a specific testing procedure that can be observed objectively. This method is without personal beliefs perceptions, biases, values, attitudes, and emotions.	Helmstadter (1970)

Research Approach

In order to address our research question, we systematically surveyed the design-related works published in the proceedings of the International Conference on Design Science Research in Information Systems and Technology (DESRIST) as well as the AIS senior scholar basket journals (AIS 2011) over a period of seven years (2012–2018). In addition to DESRIST, which is one of the most important outlets for design-related research in the IS community (Offermann et al. 2011), the eight basket journals were included due to their high methodical rigor (Hirschheim and Klein 2012), which makes them most likely to publish successful and well-documented DSR projects. The review was conducted in January 2019, following Webster and Watson (2002). To this end, we considered all issues of the European Journal of Information Systems (EJIS), Information Systems Journal (ISJ), Journal of Information Technology (JIT), Journal of the Association for Information Systems (JAIS), Journal of Management Information Systems (JMIS), Journal of Strategic Information Systems (JSIS), Information Systems Research (ISR), and MIS Quarterly (MISQ). To pre-select potentially relevant articles, we searched the entire text content of all published articles for the occurrence of either 'design science', 'design research' and 'design theory'. This search was performed with the help of the literature databases EBSCOhost (Business Source Complete), Science Direct, AIS Electronic Library, and ProQuest (ABI/Inform Complete). Due to the conference's narrow focus, we directly added all papers published in DESRIST proceedings issued between 2012–2018 to our initial literature sample. In sum, we identified 580 potentially relevant conference papers (238) and journal articles (342), which were then manually filtered. In a first selection phase, we filtered out 181 papers and articles that did not classify as completed research, including editorials, short paper, research in progress paper, prototype paper, and product paper. The remaining 399 results were then manually filtered to select those articles and papers that described completed DSR projects. We considered a published DSR project to be completed, when at least one full design cycle of artifact design and evaluation had been performed and the resulting artifact and/or derived design knowledge was presented as an adequate answer to the project's initial problem statement. Our sample selection process involved an initial inspection of the titles and abstracts followed by a detailed examination of the full text to ensure the aptness of inclusion. This resulted in our final literature sample, which comprises 191 relevant works (see **Error! Reference source not found.**).

Table 2: Reviewed Literature Sources

Name of the Outlet	Type	Period	Found works	Excluded works	Relevant works
European Journal of Information Systems	Journal	2012-2018	10	5	5
Information Systems Journal	Journal	2012-2018	36	31	5
Information Systems Research	Journal	2012-2018	15	10	5
Journal of AIS	Journal	2012-2018	54	39	15
Journal of Information Technology	Journal	2012-2018	46	41	5
Journal of MIS	Journal	2012-2018	69	52	17
Journal of Strategic Information Systems	Journal	2012-2018	15	12	3
MIS Quarterly	Journal	2012-2018	97	85	12
International Conference on Design Science Research in Information Systems and Technology (DESRIST)	Conference	2012-2018	238	114	124
Total			580	389	191

The literature sample was then coded based on a pre-defined coding scheme (Poole and Folger 1981). The coding schema was derived by examining established prior research and guidelines on DSR methodology to determine potential knowledge types, their classifications, and their sources, seeking to understand what researchers said in established prior literature. The results of this informal review are reflected in the previous section. During the coding process, knowledge sources were only considered *incipient* if they informed the first artifact design cycle of a DSR project (i.e., before artifact construction), including all previous activities (e.g., problem identification). When a paper or article referenced an overarching design research project, the related articles were examined for additional incipient knowledge sources (e.g., Tagle and Felch 2015; Tagle and Felch 2016). In doing so, we coded a total of 545 sources that are presented and discussed in the following sections.

Results and Discussion

Error! Reference source not found. presents an overview of the incipient sources of knowledge, as documented in the reviewed literature sample. During our review, we identified a total number of 545 sources distributed over 191 DSR projects. The number of sources per project ranges between 0 and 7, with an average of 2.85.

Table 4 provides an overview of how incipient knowledge is used within a DSR project. With 240 findings, most knowledge is used to inform the design of artifacts, followed by 191 findings that were used for the definition of meta requirements, 96 informed design principles, and 18 were used for building design theory. Table 4 also shows the relation of incipient knowledge types to the main outcome of the DSR project, which may or may not be directly informed by incipient knowledge. When structuring these outcomes by their contribution type (Gregor and Hevner 2013), our literature sample includes 55 DSR projects that provide a level 1 contribution (i.e., situated implementation of artifacts: 9 implemented processes, and 46 software products), 121 projects with a level 2 contribution (i.e., nascent design theory: 42 design principles, 34 methods, 38 models, 7 constructs) and 15 well-developed design theories (level 3).

Table 3: Classification of Incipient Sources of DSR Knowledge

	Design knowledge types (sources)						Tacit/explicit knowledge types (sources)		
	Kernel theories	Phenomenon knowledge	Constructs	Models	Methods	Instantiations	Tacit	Explicit	Total
Total	54 (9.9%)	171 (31.4%)	22 (4.0%)	51 (9.4%)	103 (18.9%)	144 (26.4%)	139 (25.5%)	406 (74.5%)	545
Knowledge sources (design perspective)									
Problem space	1 (0.6%)	155 (85.6%)	5 (2.8%)	11 (6.1%)	4 (2.2%)	5 (2.8%)	110 (60.8%)	71 (39.2%)	181
Solution space	53 (14.6%)	16 (4.4%)	17 (4.7%)	40 (11.0%)	99 (27.2%)	139 (38.2%)	29 (8.0%)	335 (92.0%)	364
Knowledge sources (domain perspective)									
Interdomain	45 (30.4%)	11 (7.4%)	6 (4.1%)	26 (17.6%)	40 (27.0%)	20 (13.5%)	0 (0.0%)	148 (100.0%)	148
Intradomain	9 (2.3%)	160 (40.3%)	16 (4.0%)	25 (6.3%)	63 (15.9%)	124 (31.2%)	139 (35.0%)	258 (65.0%)	397

Knowledge sources (science branch perspective)									
Natural science	7 (77.8%)	0 (0.0%)	1 (11.1%)	1 (11.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	9 (100.0%)	9
Formal science	6 (37.5%)	2 (12.5%)	3 (18.8%)	3 (18.8%)	2 (12.5%)	0 (0.0%)	0 (0.0%)	16 (100.0%)	16
Social science	18 (62.1%)	1 (3.4%)	4 (13.8%)	0 (0.0%)	4 (13.8%)	2 (6.9%)	0 (0.0%)	29 (100.0%)	29
Applied science	23 (6.9%)	47 (14.0%)	13 (3.9%)	47 (14.0%)	97 (29.0%)	108 (32.2%)	0 (0.0%)	335 (100.0%)	335
Practice	0 (0.0%)	121 (77.6%)	1 (0.6%)	0 (0.0%)	0 (0.0%)	34 (21.8%)	139 (89.1%)	17 (10.9%)	156
Knowledge sources (methodological perspective)									
Tenacity	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
Intuition	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
Authority	0 (0.0%)	6 (6.3%)	11 (11.6%)	15 (15.8%)	38 (40.0%)	25 (26.3%)	7 (7.4%)	88 (92.6%)	95
Rationalism	3 (18.8%)	9 (56.3%)	4 (25.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	16 (100.0%)	16
Empiricism	1 (0.8%)	89 (69.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	38 (29.7%)	98 (76.6%)	30 (23.4%)	128
Scientific method	50 (16.3%)	67 (21.9%)	7 (2.3%)	36 (11.8%)	65 (21.2%)	81 (26.5%)	34 (11.1%)	272 (88.9%)	306
Knowledge sources (DSR methodological perspective)									
Artifact	0 (0.0%)	4 (9.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	39 (90.7%)	9 (20.9%)	34 (79.1%)	43
Case Studies	0 (0.0%)	9 (64.3%)	1 (7.1%)	0 (0.0%)	4 (28.6%)	0 (0.0%)	13 (92.9%)	1 (7.1%)	14
Interviews	0 (0.0%)	72 (96.0%)	0 (0.0%)	2 (2.7%)	0 (0.0%)	1 (1.3%)	75 (100.0%)	0 (0.0%)	75
Literature	54 (14.8%)	51 (14.0%)	19 (5.2%)	47 (12.9%)	95 (26.1%)	98 (26.9%)	0 (0.0%)	364 (100.0%)	364
Other methods	0 (0.0%)	25 (65.8%)	2 (5.3%)	1 (2.6%)	4 (10.5%)	6 (15.8%)	31 (81.6%)	7 (18.4%)	38
Surveys	0 (0.0%)	10 (90.9%)	0 (0.0%)	1 (9.1%)	0 (0.0%)	0 (0.0%)	11 (100.0%)	0 (0.0%)	11

In general, we found that DSR projects are mainly informed by explicit knowledge (74.5%). Explicit knowledge is primarily drawn from the solution space (82.5%) and is based on scientific methods (67.9%). The main branch of science from which the explicit knowledge stems is applied sciences (82.5%), which is also the science branch all reviewed DSR projects can be attributed to. Further, the majority of explicit knowledge (63.6%) is used to inform DSR projects that try to solve problems from the very same domain the knowledge originated from. This strong reliance on intradomain knowledge sources can also be seen in the case of tacit knowledge use, where we found no example for tacit knowledge that was gathered outside the focal domain of a DSR project. In the reviewed works, we also did not find any clear statements regarding the direct use of tacit knowledge to motivate or inform the construction of an IT artifact. Hence, in order to differentiate between the two incipient knowledge types, we assessed the type of knowledge based on its original nature before it was explicated by a researcher. In doing so, we found that tacit knowledge is predominantly used to inform or evaluate the problem of interest in DSR projects (60.8%). As to be expected, we also found that tacit knowledge in DSR is exclusively gathered in practice (i.e., the respective application environment), and explicated through different capturing methods, such as interviews, focus groups, workshops, and observations. One key takeaway for design researchers from these considerations is that explicit and tacit knowledge are both relevant incipient knowledge types that should both be considered in the early stages of a DSR project. Another takeaway is that design researchers should focus on intradomain sources for both knowledge types, although in case of explicit knowledge, interdomain sources should be examined as well.

Table 4: Consumption of Incipient Knowledge by DSR Papers

	Design knowledge types (sources)						Tacit/explicit knowledge types (sources)		
	Kernel theories	Phenomenon knowledge	Constructs	Models	Methods	Instantiations	Tacit	Explicit	Total
Total	54 (9.9%)	171 (31.4%)	22 (4.0%)	51 (9.4%)	103 (18.9%)	144 (26.4%)	139 (25.5%)	406 (74.5%)	545
Direct use of incipient knowledge in DSR papers									
Meta Requirements	2 (1.0%)	58 (30.4%)	14 (7.3%)	11 (5.8%)	27 (14.1%)	79 (41.4%)	44 (23.0%)	147 (77.0%)	191
Artifact design	34 (14.2%)	101 (42.1%)	2 (0.8%)	30 (12.5%)	67 (27.9%)	6 (2.5%)	78 (32.5%)	162 (67.5%)	240
Design principles	11 (11.5%)	8 (8.3%)	5 (5.2%)	6 (6.3%)	8 (8.3%)	58 (60.4%)	15 (15.6%)	81 (84.4%)	96
Design theory	7 (38.9%)	4 (22.2%)	1 (5.6%)	4 (22.2%)	1 (5.6%)	1 (5.6%)	2 (11.1%)	16 (88.9%)	18
Research contribution types of DSR papers (research output)									
Processes (Level 1 contr.)	2 (6.7%)	9 (30.0%)	1 (3.3%)	1 (3.3%)	9 (30.0%)	8 (23.7%)	11 (36.7%)	19 (63.3%)	30
Software products (Level 1 contr.)	5 (3.8%)	46 (34.8%)	6 (4.5%)	1 (0.8%)	16 (12.1%)	58 (43.9%)	48 (36.4%)	84 (63.6%)	132
Design principles (Level 2 contr.)	14 (8.1%)	56 (32.6%)	9 (5.2%)	18 (10.5%)	34 (19.8%)	41 (23.8%)	40 (23.3%)	132 (76.7%)	172
Methods (Level 2 contr.)	11 (12.5%)	22 (25.0%)	2 (2.3%)	7 (8.0%)	20 (22.7%)	26 (29.5%)	13 (14.8%)	75 (85.2%)	88
Models (Level 2 contr.)	5 (7.2%)	20 (29.0%)	1 (1.4%)	18 (26.1%)	19 (27.5%)	6 (8.7%)	16 (23.2%)	53 (76.8%)	69
Constructs (Level 2 contr.)	1 (7.7%)	5 (38.5%)	0 (0.0%)	2 (15.4%)	2 (15.4%)	3 (23.1%)	5 (38.5%)	8 (61.5%)	13
Design theory (Level 3 contr.)	16 (39.0%)	13 (31.7%)	3 (7.3%)	4 (9.8%)	3 (7.3%)	2 (4.9%)	6 (14.6%)	35 (85.4%)	41

From the methodological perspective, we found no indication that either tenacity or intuition was used as an incipient source of knowledge in the reviewed DSR works. Which is not surprising, considering that superstitions, traditions, and intuition are ill-suited as a method of knowing if the knowledge is to be reliable (Helmstadter 1970), which is certainly the case in DSR. On the other hand, we found the methods of authority (95) and empiricism (128) as well as scientific methods (306) to be the main sources of incipient knowledge. In terms of specific methods informing DSR, we found literature reviews (364) to be by far the most common source of incipient knowledge, followed by interview studies (75) and the inspection of existing IT artifacts (43). In terms of methodological source variety, we found knowledge about a phenomenon of interest to be the most diverse. On the one hand, this indicates that design researchers investigate a large number of different phenomena, which can be informed and investigated in a variety of ways. On the other hand, the finding should be interpreted as encouragement for design researchers to not limit themselves to a specific methodological approach when gathering knowledge about the phenomenon of interest.

Another finding from our review is that knowledge about instantiations is acquired from two major sources: actual artifacts from practice and published research on artifacts. Contrary to intuition, we found literature to be the far more common source of instantiation knowledge (98) when compared to direct investigations of existing instantiations (39). It seems reasonable that a direct examination of existing instantiations would be a more effective approach to learn about their design. This notion is underlined by DSR methodological literature, which regards implemented artifacts as a valuable knowledge input in DSR (Hevner et al. 2004). One possible explanation for our finding could be that in practice such artifact implementations are often not readily accessible (e.g., corporate IT systems or components of critical infrastructures) and are, therefore, difficult to examine. The finding may also indicate that design researchers are more comfortable with citing scientific sources as a means for establishing research rigor. Regardless of the reason, based on our review, it seems to be a viable approach for design researchers to rely on scientific publications as an incipient source of design knowledge on artifact instantiations. However, such published design knowledge might not always be available, especially when investigating emerging technology trends. Distributed ledger technology (DLT) is a prime example of such a trend, as its current advancements are driven from practice and not science (Glaser and Bezzenberger 2015; Kannengießer et al. 2019; Sankar et al. 2017). Researchers that do not consider extant technology instantiations as an incipient design knowledge source, risk reinventing already existing solutions with no actual contribution to the design knowledge base. For this reason and based on our findings, a stronger emphasis on direct knowledge collection from practice in terms of instantiated artifacts in use could be one possible angle for future methodological contributions in DSR.

In light of the previous discussions, it is less surprising that we found the problem space to be the main source of knowledge for the phenomenon of interest (90.6%). The solution space, on the other hand, is the main source for all other design knowledge types, namely kernel theories (98.2%), constructs (77,3%), models (78.4%), methods (96.1%), and instantiations (96.5%). This diversity is reversed when comparing the problem and solution space as sources for tacit and explicit knowledge. While the problem space provides both types of knowledge, the solution space is mainly used as a source for explicit knowledge (92%). When comparing problem and solution space in terms of total number of used sources, another noteworthy finding is that the reviewed DSR projects make more use of the solution space as a source of incipient knowledge when compared to the problem space. This raises the question of whether problem understanding in DSR is less driven by external, incipient knowledge and instead relies more on the design researchers' internalized knowledge and experience. Another explanation for this finding could be that the design of innovative artifacts is often accomplished through combination of multiple design inputs (Vaishnavi and Kuechler 2004), which requires design researchers to explore the solution space from multiple angles. As actionable advice derived from our review results, it is sensible to consider both tacit and explicit knowledge about the phenomenon of interest when exploring the problem space (e.g., a literature review on the investigated problem, interviews with domain experts, surveys, and other methods like focus groups). When investigating the potential solution space, the focus should be on identifying explicit knowledge and should not be limited to one design knowledge type, even though the investigation of existing design artifact instantiations seems in most cases a promising starting point for exploring the solution space.

Finally, from the perspective of domains as sources of incipient knowledge, we found that most knowledge used in the early stages of DSR originates from the same domain in which the phenomenon of interest resides (72.8%). As discussed before, the main sources of phenomenon knowledge and existing instantiations can be classified as intradomain. There are, however, a few exceptions. From both science-branch and domain perspective, kernel theories are the most diversely sourced type of incipient knowledge. In line with the definitions from extant literature (Goldkuhl 2004; Nunamaker et al. 1990; Orlikowski and Iacono 2001; Simon 1996; Venable 2006b; Walls et al. 2004), we found kernel theories to originate from all science branches. Also, from the domain perspective, our analysis shows that DSR projects frequently incorporate methods and models from outside their focal domain. Nonetheless, the finding that the overall majority of incipient knowledge can be characterized as intradomain is at odds with recommendations from DSR methodological literature (e.g., Nunamaker et al. 1990; Vaishnavi and Kuechler 2004). This raises the question as to what causes this phenomenon and whether it is a desirable development or a latent problem in the DSR community. We consider the further investigation of this phenomenon to be a valuable opportunity for future research.

Closing this section, two limitations of the current study need to be pointed out. The first limitation concerns the selection of reviewed outlets. In order to keep the literature sample at a manageable size, we limited our sample to the selection of journals and conference proceedings listed Table 2. While we are confident that our outlet selection and the selected timeframe provided us with a good representation of current DSR practice, the analyzed literature sample is not exhaustive. A much larger variety of outlets for DSR contributions exist, including conferences with dedicated DSR tracks (e.g., ICIS, ECIS, AMCIS) as well as numerous journals open to design-related contributions. Future research might examine these additional DSR outlets to extend our review and gain further insights into DSR knowledge sources and methodological patterns. The second limitation of this work stems from the literature-based research design, which subjects our study to the inherent limitation of analyzing published work. Our research approach collected self-reported knowledge input of DSR works. The study, therefore, only allows conclusions about the knowledge sources considered in the DSR literature, which does not necessarily align with knowledge sources used in practice. Researchers might report only those knowledge sources they deem most important or influential for their work. Furthermore, as one of the reviewers of this paper remarked, there could be biases between different knowledge types, which lead design researchers to not report certain knowledge sources (e.g., tenacity or intuition) that may dissuade reviewers and editors from accepting the paper. Future research will be necessary to evaluate the existence of such biases and their influence on DSR, in particular in terms of scholarly communication

Conclusion

In this paper, we set out to identify and analyze the incipient sources of knowledge in DSR. To this end, we reviewed 191 DSR project published in the International Conference on Design Science Research in Information Systems and Technology as well as the AIS senior scholar basket journals reaching back seven years. On the basis of this literature sample, we analyzed and classified the incipient sources of DSR knowledge that informed the initial artifact design cycles of the described DSR projects, including all preceding activities (e.g., problem identification). This paper thereby contributes to the DSR literature stream by providing foundational insights into the DSR community and thereby paves the way for novel methodological contributions.

Future research may utilize our work as a starting point for further explorations of the nature of design science knowledge, for instance by incorporating additional phases of DSR. Furthermore, our results could help to create methodological contributions in the DSR community in the form of novel guidelines or research processes that, in particular, guide the selection of appropriate incipient knowledge sources.

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