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Construction of Design Science Research Questions

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Abstract:

Posing research questions represents a fundamental step to guide and direct how researchers develop knowledge in research. In design science research (DSR), researchers need to pose research questions to define the scope and the modes of inquiry, characterize the artifacts, and communicate the contributions. Despite the importance of research questions, research provides few guidelines on how to construct suitable DSR research questions. We fill this gap by exploring ways of constructing DSR research questions and analyzing the research questions in a sample of 104 DSR publications. We found that about two-thirds of the analyzed DSR publications actually used research questions to link their problem statements to research approaches and that most questions focused on solving problems. Based on our analysis, we derive a typology of DSR question formulation to provide guidelines and patterns that help researchers formulate research questions when conducting their DSR projects.

Keywords: Design Science Research, Research Question, Research Question Formulation, Research Question Construction.

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1 Introduction

Design science research (DSR) has become a popular and distinctive research paradigm in the information systems (IS) discipline. Major IS journals, such as *MISQ*, *JAIS*, *BISE*, and *CAIS*, have not only accepted DSR papers but also dedicated several special issues to the paradigm (March & Storey, 2008; vom Brocke, Hevner, & Maedche, 2017a; vom Brocke, Hevner, Maedche, & Winter, 2017b). Furthermore, many researchers have adopted DSR to investigate a wide range of topics, such as decision support systems, management strategies, modeling tools, healthcare systems, and computational models and algorithms (Goes, 2014; Rai, 2017). In particular, about 80 percent of research related to decision support systems has applied DSR (Arnott & Pervan, 2012).

With its focus on artifact development, utility, innovation, and iteration, DSR contributes a distinctive paradigmatic approach to research and complements other ways to conduct science, such as the behavioral sciences. In particular, DSR helps researchers to develop innovative and useful artifacts, while behavioral science helps researchers to ascertain the truth in order to understand a certain phenomenon (Hevner, March, Park, & Ram, 2004; Niederman & March, 2012). DSR's distinctive approach includes specific methodological concerns and knowledge contribution types that require special attention to constructing suitable research questions.

Constructing clear research questions represents a fundamental step in any research study because they indicate what the study is about and convey its essence (Dubé & Paré, 2003; Hassan, 2017; Venkatesh, Brown, & Bala, 2013). Several disciplines across the behavioral and the natural sciences have illustrated this fundamental role (Creswell, 2009; Hällgren, 2012; Miles, Huberman, & Saldaña, 2014), while numerous researchers, including Recker (2012), Sandberg and Alvesson (2013), and Bryman (2015), have provided helpful advice for constructing research questions. Here, the question arises how to suitably reflect DSR's distinctive nature in DSR research questions. Consider, for instance, the following three examples:

- In the behavioral sciences, researchers often link research questions to explaining phenomena through causal relationships, which they usually express in the form "does X cause Y?". Can we adopt this type of question in DSR? A good fit seems hardly probable because DSR builds innovative, useful (classes of) artifacts for specific (classes of) contexts with concerns for feasibility and improvement but not for statistical generalizability (Mettler, Eurich, & Winter, 2014).
- In the natural sciences (e.g., physics and biology), research questions often concern how and why things are in order to identify natural laws that pertain to reality (March & Smith, 1995). When constructing and approaching these kinds of questions, researchers need to follow the key principle that they and research objects are independent. For example, electrons are separate from the physicists who observe them (Weber, 2004). In DSR, however, applying this principle seems impractical, if not impossible, since research objects represent the design artifacts that researchers construct deliberately.
- DSR-specific research questions often concern developing artifacts (e.g., "how can we develop X?" or "how can we develop X to resolve Y?"). However, this type of question leads to conjectures that one cannot easily falsify. That is, the questions do not pertain to a phenomenon that one can test as either true or false but to a phenomenon that necessarily leads to a positive outcome. The latter occurs because one can repeatedly develop and evaluate artifacts until one achieves positive results.

Despite these challenges, we fundamentally agree with Gregor and Hevner (2013): researchers need clear research questions that foster maximum publication impact, open up both the problem and solution spaces, and either improve current artifacts or develop new ones. We also agree with Hevner and Chatterjee (2010), who consider the research question the most important item in their DSR checklist. However, researchers have provided little guidance on how to construct DSR questions. Prior research focused on the general principles guiding DSR (Hevner et al., 2004), on broad views of the research process (Hevner & Chatterjee, 2010; Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007), and on ethical issues regarding the responsibilities of researchers who conduct DSR (Myers & Venable, 2014). This lack of guidance (and the difficulties it causes) may arise from a combination of multiple factors: the DSR paradigm's relative recentness, DSR's diversity, and the different contributions to knowledge generating design products and design processes (Gregor & Hevner, 2013; Rai, 2017). Based on this gap, we address the following research question (RQ):

RQ: How can we construct research questions in line with the DSR paradigm's nature and purpose?

By addressing this research question, we make three contributions. First, we identify and analyze the main arguments for constructing DSR research questions according to the core literature. To do so, we review 104 publications from different outlets that explicitly state that they follow the DSR paradigm. Second, we propose and discuss a typology for formulating DSR research questions based on synthesizing current practices. The synthesis examines common ways and patterns of formulating DSR research questions. Based on this foundation, we provide researchers with guidelines on constructing and formulating research questions that fit the DSR paradigm. Please note that we do not regard our guidelines as mandatory. Instead, we hope to inspire DSR researchers to construct, formulate, and reformulate suitable research questions throughout their research process and, during the associated rigor, design, and relevance cycles, to guide their inquiry. Finally, we highlight that the DSR paradigm involves unique ways of constructing suitable research questions, which contribute to positioning it as a distinctive research paradigm.

We structure the paper as follows: In Section 2, we review the role of research questions in the IS discipline in general and in DSR in particular. In Section 3, we develop an analytical framework for our DSR publication analysis. In Section 4, we describe the literature review method we adopted in this study. In Section 5, we present the analysis results and findings from the review, while, in Section 6, we show how DSR constructs research questions in detail. In Section 7, we propose a typology for formulating DSR research questions. In Section 8, we discuss the findings and their implications. Finally, in Section 9, we conclude the paper and discuss future work.

2 The Role of Research Questions

Research questions play a key role in academic research. Researchers use research questions to represent what their study addresses, investigates, and, ultimately, answers. Research methodology textbooks repeatedly highlight research questions' importance and emphasize that one should carefully define them (Creswell, 2009; Recker, 2012). Recker (2012), for instance, notes that "a research question should be a key statement that identifies the phenomenon to be studied. The research question(s) is/are the fundamental cornerstone around which your whole [doctoral] research revolves and evolves" (p. 27). Alvesson and Sandberg (2013) maintain that "without posing questions it is not possible to develop our knowledge about a particular subject" (p. 11). In other words, research questions represent the required starting point to develop knowledge in academic research.

In the IS discipline, we identify three key roles for research questions: 1) defining the research scope, 2) guiding the research process, and 3) positioning the contributions. The first role narrows the research focus from broad statements to specific questions to answer. Supporting this argument, Creswell (2009) suggests that research questions make the type of research (e.g., qualitative, qualitative, mixed) more explicit and shape its boundaries. Research questions should also represent researchers' investigative direction and, therefore, delimit the perimeter of analysis (Bryman, 2007). In a similar vein, Miles et al. (2014) and Dubé and Paré (2003) suggest using research questions to define an IS study's focus.

Second, research questions frame the research process decisions, which specifically include the key decision about which method to use. The research questions guide researchers to choose "the most appropriate course of study that could be undertaken in order to answer the question[s]" (Recker, 2012, p. 31). For example, case study methods suit work that addresses "why" and "how" questions (Benbasat, Goldstein, & Mead, 1987). Järvinen (2008) goes a step further and proposes a taxonomy that, given their formulated research questions, IS researchers can use to choose suitable research methods. In addition, many researchers use research questions to guide data collection and analysis.

Third, research questions allow researchers to position their research contributions. Alvesson and Sandberg (2013) suggest that researchers answer research questions ultimately to contribute to the human knowledge base by either bridging a knowledge gap in the literature or producing original knowledge. Research questions also allow researchers to communicate their research contributions (Rosemann & Vessey, 2008). In other words, if IS research questions do not lead to knowledge contributions and help communicate them, they do not represent good research questions. On the whole, these roles highlight the crucial function of research questions in IS research.

While DSR forms a distinct research paradigm in the IS discipline, three basic roles of research questions also apply to it: 1) to define a project's scope (Hevner et al., 2004; Nunamaker, Chen, & Purdin, 1990), 2) to drive the research process (Järvinen, 2008; Offermann, Levina, Schönherr, & Bub, 2009), and 3) to position a project's contributions (Gregor & Hevner, 2013; March & Smith, 1995).

However, the DSR literature also mentions two additional roles. First, only by posing innovative research questions can we achieve innovative artifacts, which design science targets (Gregor & Hevner, 2013; March & Storey, 2008). Routine questions about artifacts that refer to known solutions to known problems have no place in design science (Gregor & Hevner, 2013). Thereby, DSR research questions focus on helping one to characterize design artifacts' innovative aspects. Second, DSR targets a knowledge void by posing relevant questions (Hevner & Chatterjee, 2010). By balancing relevance and rigor, good DSR research questions lead to knowledge contributions and practical contributions (Gregor & Hevner, 2013; Hevner, 2007). Further, formulating research questions seems to be common (although not uniformly adopted) practice in DSR publications. As we show later in this paper, about two-thirds of the DSR papers we examined relied on research questions to frame their research, while the remaining ones relied on other alternatives, such as formulating research problems and design requirements.

Given the importance of research questions, we should expect to find guidelines in the related literature to help researchers construct and formulate DSR-specific research questions. However, to the best of our knowledge, no such guidelines exist. The best approximations include guidelines for identifying high-level genres of inquiry (Baskerville, Kaul, & Storey, 2015) and a generic framework for identifying research objectives (Alismail, Zhang, & Chatterjee, 2017). This lack of guidance may contribute to why many DSR papers do not use research questions, which may mean that the paper might not realize its full knowledge contribution potential. With this study, we bridge that gap by analyzing recent DSR publications to synthesize guidelines on how to construct and formulate suitable DSR research questions.

3 Analytical Framework

In order to answer our research question, we first developed an analytical framework to help focus and bound our data collection by providing anticipatory data reduction (Miles et al., 2014). In our specific case, the analytical framework provides the structure required to analyze DSR publications with respect to how researchers constructed research questions in their studies. As characteristic of qualitative analysis, the framework also identifies the constructs we needed to later extract the fundamental elements related to DSR questions.

We developed our framework based on two foundations: prior research on constructing research questions (as a methodological concern that cuts across almost every discipline) (Alvesson & Sandberg, 2013; Hassan, 2017; Higginbotham, 2001) and the conceptualization and justification of design science as a distinctive research paradigm (Gregor & Hevner, 2013; Hevner et al., 2004; Nunamaker et al., 1990).

Figure 1 shows our proposed analytical framework. The framework highlights the three key activities of the research question lifecycle: construction, formulation, and answer. Construction refers to how a researcher identifies opportunities for contributing to knowledge and builds key arguments to scaffold the research (Alvesson & Sandberg, 2013; Gregor & Hevner, 2013). This activity establishes the goals, motivations, and contexts for conducting the research. Formulation occurs when the researcher conveys the goals as specific research questions. A common skeleton for formulating research questions combines form (what, how, why, who, and what?) and substance (what the research is about?) (Järvinen, 2008; Yin, 2013). Answer refers to the research process that one conducts to finally answer the research questions. In DSR, this activity generates innovative useful artifacts to provide knowledge and practical contributions (Hevner & Chatterjee, 2010; Hevner et al., 2004). Given the three activities, we identify the following seven core framework elements:

- Every study has a research **motivation**
- The research motivation contextualizes a **problem statement**
- The problem statement raises **research questions**
- The research questions drive the **research approach**
- The research approach is framed by **theory in use**
- The research approach suggests **research activities**, and
- Research activities generate IS **artifacts.**

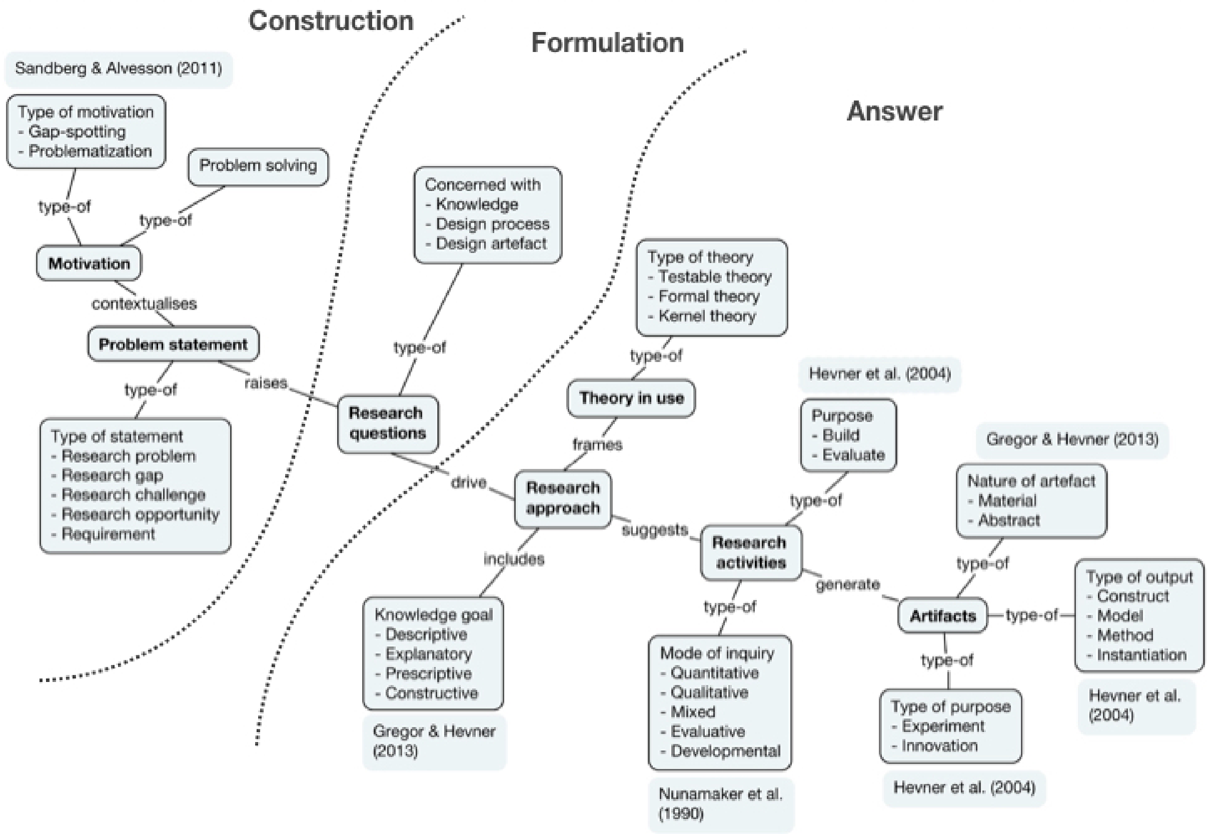

Figure 1. Analytical Framework

3.1 Research Motivation

Sandberg and Alvesson (2011) identify two major motivations for constructing research questions: gap spotting and problematization. Gap spotting refers to identifying gaps in prior literature, which leads to research questions that extend existing knowledge. Different types of gaps, including confusion in the existing literature, underresearched areas, overlooked areas that lack a specific focus, and areas that lack empirical support, motivate gap-spotting research. Problematization generates research questions by challenging well-established assumptions that underpin prior theory and knowledge. Logic-breaking arguments that go beyond a particular theory motivate problematization research. Problematization research may challenge different levels and scopes of assumptions, which includes in-house, root-metaphor, paradigm, ideology, and field assumptions (Alvesson & Sandberg, 2013). We add a new motivation for DSR to the existing two: problem solving, which reflects DSR's problem-solving nature (Pries-Heje & Baskerville, 2008). A practical and/or knowledge problem that one can solve by creating IS artifacts motivates problem-solving research.

3.2 Problem Statement

The problem statement articulates the problem that the DSR study addresses. Since DSR normally addresses wicked problems, the problem statement helps researchers to define the research problem (Peffers et al., 2007), clarify its relevance (Hevner & Chatterjee, 2010), and identify the class of problems to which the addressed problem belongs (Gregor & Hevner, 2013). Experience shows that different DSR publications have different ways of presenting their problem statement: as a research problem, research gap, research challenge, research opportunity, and also as a list of requirements that a designed artifact needs to satisfy.

3.3 Research Questions

Research questions establish a DSR project's focus. Good research questions define what the DSR project concerns and convey its essence (Hevner & Chatterjee, 2010; Sandberg & Alvesson, 2011). Since we show the roles of DSR research questions in Section 2, we now focus on formulating DSR research questions. As we note in Section 2, no current guidelines for formulating DSR research questions exist. The DSR literature suggests that many DSR studies concern the design process while others concern the design product (Hevner et al., 2004). Consequently, we expect types of questions related to both design process and design product. The process type focuses on "how" to move rationally from a particular problem to a solution (Gregor, 2006), while the product type focuses on "which" types of artifacts DSR research generates. Finally, the last question type we consider focuses on "what is", which refers to knowledge informing, being challenged by, and originating from the research.

In relation to other elements, the research questions link the problem statements to the research approach. In the former relationship, research questions may arise from problem statements and refine and direct them to specific directions for inquiry (Offermann et al., 2009; Recker, 2012). As such, many DSR publications pose research questions as a single sentence in order to frame the problem statement. In the latter relationship, research questions drive the subsequent DSR approach as they set the directions for the selection of suitable research methods and research design to answer these questions (Järvinen, 2008).

3.4 Research Approach

At this stage, the research approach refers to how the researchers position their worldviews regarding their study (Creswell & Tashakkori, 2007). Järvinen (2008) and Creswell (2009) suggest that different research approaches link to different research question formulations when pursuing different knowledge goals. Gregor and Hevner (2013) characterize research approaches' common knowledge goals as descriptive, explanatory, prescriptive, or constructive.

3.5 Theory in Use

The theory in use concerns the theoretical statements that support the research approach. In this element, we find testable theory (which seeks to explain a phenomenon (Weber, 2012)), formal theory (which uses mathematics and logic (Bichler et al., 2016)), and kernel theory (which adopts theory from other fields (Gregor & Hevner, 2013)). Since the DSR literature may use other categories of theories, the framework is open to emerging categories when a researcher subsequently analyzes the literature.

3.6 Research Activities

We understand building and evaluating to represent DSR's main activities as Hevner et al. (2004) suggest. The building activity develops artifacts that enquire about the research question. The evaluating activity assesses the artifacts to show their utility. We also draw on the different modes of inquiry that Nunamaker et al. (1990) suggest: quantitative, qualitative, mixed, developmental, and evaluative.

3.7 Artifacts

Artifacts refer to the main DSR outcomes. The related literature contains different schemas to classify artifacts by addressing their nature, their type of purpose, and their type of output. Gregor and Hevner (2013) characterize artifacts' nature as either material or abstract. Hevner et al. (2004) characterize artifacts' purpose as either experiments or innovations. They also suggest four different types of outputs: constructs, models, methods, and instantiations. We do not discuss these different elements in detail and refer readers to the aforementioned references.

In sum, the analytic framework that Figure 1 depicts highlights the main elements of the research question's lifecycle. Note that this framework remains open to more detailed elements. We explore such elements when we analyze published DSR research in the following sections. Since DSR has evolved rapidly as a research paradigm, the framework also remains open to new DSR advancements. With this openness in mind, we used the framework to guide our data analysis.

4 Methodology

In the current study, we follow the literature-review method that has certain strengths and weaknesses when analyzing the DSR research questions' construction. On the one hand, by simply reviewing research questions in DSR publications, we cannot examine how researchers constructed them when they began their DSR projects or how they evolved over time. On the other hand, while "it is difficult to assess what research texts [publications] may say about how researchers really came up with their research questions at the beginning of their projects, the research text can be seen as the key stage in the formulation of research questions" (Sandberg & Alvesson, 2011, p. 25). Consequently, reviewing how a particular publication refers to its DSR research questions allows one to understand the logic behind its claims. We can also examine how researchers constructed and formulated their final research questions by aligning the written research motivation, problem statement, research approach, research activities, and outcome artifacts. Further, in line with Sandberg and Alvesson (2011) and Hällgren (2012), the literature review method represents an appropriate method for analyzing and synthesizing research questions' construction. On the whole, this method enables one to extract and synthesize how the DSR literature has constructed research questions.

In our literature review, we follow Webster and Watson's (2002) recommendations, which focus on increasing transparency and reliability. We explicitly followed the following three review stages: define scope, extract data, and synthesize data. Table 1 summarizes these stages, and we describe them in detail below.

Table 1. Three Literature Review Stages

Activity	Description	Results
Define scope	Select DSR publications for review	Dataset of 104 publications (21 *MISQ* papers, 20 PhD dissertations, and 63 papers published in the proceedings of DESRIST and HICSS)
Extract data	Extract the elements related to research questions	List of codes extracted from each reviewed publication (according to the analytical framework as reference)
Synthesize the extracted data	Compare, merge, and synthesize the extracted codes	Ways of constructing and formulating DSR questions

4.1 Define Scope

We searched for both mature and recently started DSR studies to form a representative pool of DSR publications. We surveyed both academic papers and PhD dissertations to find mature DSR studies. Specifically, we surveyed *MISQ* for DSR papers that appeared between 2006 and 2017 and, thereby, extended Gregor and Hevner's (2013) list of papers to include papers published from 2014 to 2017. We initially searched for PhD dissertations via ProQuest Dissertations and Theses Global using the keywords "design science" and filtering "doctoral dissertations" between 2006 and 2017. We explored the search results to identify dissertations that explicitly stated they had adopted the design science paradigm. When more sources emerged, we decided to focus on 20 frequently cited dissertations. By including the doctoral dissertation genre, we opened our analysis to more extensive documentations of research activities. This openness includes the secondary artifacts used to support primary artifacts' development (Bertelsen, 2000), which published papers may deliberately omit to improve their conciseness. Further, we included papers from the DESRIST and HICSS conferences published in 2016 and 2017 to find emerging DSR studies. Researchers generally recognize these two conferences as embracing the DSR paradigm.

In both cases, we specifically selected papers with a clear focus on design science per se; thus, we excluded literature reviews, editorials, and research notes. Our final dataset contained 104 publications (i.e., 63 papers from DESRIST and HICSS (emerging publications), 21 papers from *MISQ* (mature publications), and 20 PhD dissertations (extensive publications)). Appendix A presents a complete list of the publication dataset. One should not regard this dataset as comprehensive but as a representative sample of various DSR literature genres.

4.2 Extract Data

We developed a coding form to extract data about research questions and their related elements. We derived this coding form directly from the analytical framework (Figure 1), and it considered the following dimensions: 1) essential information required to identify the reviewed publication; 2) the research motivation and corresponding type; 3) the problem statement and corresponding type; 4) the various research questions (if any) limited to a maximum of four, the corresponding type, and specific terms characterizing the research questions; 5) the research approach, including the adopted theory (if any) and type of knowledge goals; 6) the research activities and type of inquiry adopted in the publication to address the research questions; and 7) the artifacts and their nature, their type of purpose, and their type of outputs. These elements provided the key logic of how the publications had constructed, formulated, and answered their DSR research questions.

We applied the coding form to all 104 publications for data extraction. Following Okoli's (2015) recommendations, we iteratively tested and adjusted the coding form by using a subset of the sources until we reached agreement. We then carefully read each publication and looked for the coding dimensions. Following Kitchenham and Charters (2007), two of the authors conducted the coding process, while the third author randomly checked 20 percent of the coded items. When we identified disagreements, we discussed them in detail to reach consensus. During the coding process, if a DSR publication explicitly offered statements on research question construction and formulation, we noted these statements and analyzed and synthesized them afterwards.

4.3 Synthesize Data

In this stage, we merged and synthesized the extracted data about how papers constructed their DSR research questions. This synthesis involved four steps. First, we reviewed the data that we had extracted to the coding form to identify how the papers used their research questions. Second, we merged and grouped related research questions into categories. For instance, we grouped the questions "how can competitive simulation games be used to [ ]?" and "how can the emerging hardware design and content design [ ] be leveraged by retail stores to [ ]?" into the "how can we [use]?" type of questions. Third, we synthesized the research question-related elements, such as the research motivation, problem statement, and theoretical foundation, which provide the key logic for constructing a research question. We adopted Sandberg and Alvesson's (2011) typology for structuring research questions for the synthesis. Fourth, we mapped the research questions to the research approaches, activities, and outcome artifacts to determine their relationships. During this procedure, we also compared the data of the different DSR publications' genres. In section 5, we report the results from the synthesis.

5 Results

In this section, we report our research findings. Out of the 104 analyzed DSR publications, 64 publications had at least one research question. As we expected, emerging publications (conference papers) had fewer research questions than mature and extensive publications (*MISQ* papers and dissertations). This finding suggests that the emerging publications either reflect ongoing or more focused research. Interestingly, 40 publications lacked a specific research question, which, to some extent, confirms the challenge of formulating research questions in DSR.

Table 2 summarizes the detailed analysis results: how the papers constructed their research questions, used them, and addressed them. From Table 2, note that the number of publications in a dimension and the total number of publications in its categories may not amount to the same number because, in some cases, a publication considered multiple values of a dimension, and, thus, we coded it multiple times (e.g., we found multiple research questions for Lau, Liao, Wong, and Chiu's (2012) paper and coded them accordingly). In other cases, a publication did not clearly reflect the dimension and we coded it as "not applicable".

Table 2. Summary of Results (N = 104)

#	Dimension	Value	Conference papers		MISQ papers		Dissertations		Total	
			N = 63	%	N = 21	%	N = 20	%	N = 104	%
Research question construction										
1	Motivation	Problem solving	51	81.0%	18	85.7%	11	55.0%	80	76.9%
		Gap spotting	21	33.3%	8	38.1%	13	65.0%	42	40.4%
		Problematization	1	1.6%	1	4.8%	1	5.0%	3	2.9%
2	Problem statement	Research challenge	18	28.6%	11	52.4%	9	45.0%	38	36.5%
		Research gap	15	23.8%	5	23.8%	6	30.0%	26	25.0%
		Research problem	12	19.0%	2	9.5%	3	15.0%	17	16.3%
		Requirement	11	17.5%	2	9.5%	0	0.0%	13	12.5%
		Research opportunity	5	7.9%	1	4.8%	1	5.0%	7	6.7%
Research question formulation										
3	Usage of RQ	Yes	36	57.1%	14	66.7%	14	70.0%	64	61.5%
		No	27	42.9%	7	33.3%	6	30.0%	40	38.5%
4	RQ types	Design process (how?)	35	55.6%	27	128.6%	18	90.0%	80	76.9%
		Design product (which?)	3	4.8%	2	9.5%	15	75.0%	20	19.2%
		Knowledge (what is?)	0	0.0%	0	0.0%	3	15.0%	3	2.9%
		Other	3	4.8%	2	9.5%	1	5.0%	6	5.8%
5	Research approach: knowledge goal	Exploratory	24	38.1%	4	19.0%	5	25.0%	33	31.7%
		Prescriptive	17	27.0%	8	38.1%	7	35.0%	32	30.8%
		Constructive	7	11.1%	4	19.0%	1	5.0%	12	11.5%
		Confirmatory	7	11.1%	2	9.5%	1	5.0%	10	9.6%
		Explanatory	6	9.5%	0	0.0%	1	5.0%	7	6.7%
		Descriptive	2	3.2%	2	9.5%	3	15.0%	7	6.7%
6	Research activities: mode of inquiry	Developmental	30	47.6%	9	42.9%	14	70.0%	53	51.0%
		Evaluative	3	4.8%	1	4.8%	0	0.0%	4	3.8%
		Mixed (developmental and evaluative)	26	41.3%	9	42.9%	4	20.0%	39	37.5%
7	Theory in use	No specific theory	34	54.0%	3	14.3%	10	50.0%	47	45.2%
		Kernel theory	13	20.6%	14	66.7%	5	25.0%	32	30.8%
		Formal theory	4	6.3%	3	14.3%	4	20.0%	11	10.6%
		Testable theory	0	0.0%	1	4.8%	1	5.0%	2	1.9%
8	Outcome artifacts	Instantiation	19	30.2%	6	28.6%	3	15.0%	28	26.9%
		Model	15	23.8%	4	19.0%	4	20.0%	23	22.1%
		Method	6	9.5%	2	9.5%	3	15.0%	11	10.6%
		Construct	3	4.8%	2	9.5%	4	20.0%	9	8.7%
		Model and instantiation	11	17.5%	3	14.3%	2	10.0%	16	15.4%
		Construct, model, and instantiation	3	4.8%	0	0.0%	3	15.0%	6	5.8%

5.1 Research Question Construction

The results show that the DSR papers focused mainly on solving problems: 76.9 percent of the reviewed publications constructed their research by basing it on stated problems. In constructing research questions in this way, DSR publications use a practical problem, design problem, or research challenge as their motivation (Ketter, Peters, Collins, & Gupta, 2016; Mramba, Tulilahti, & Apiola, 2016). Many papers also used gap spotting, which focuses on addressing an identified research gap, to construct questions. The fewest number of papers used problematization. In particular we could identify only three publications that challenged existing theories' assumptions (e.g., Pigott, 2012; Sahoo, Singh, & Mukhopadhyay, 2012; Tofangchi, Hanelt, & Kolbe, 2017).

We now consider how DSR publications state their problems: 36.5 percent identified research challenges (i.e., problems with the research's complexity and scope) in order to present their problem statements. Ketter et al. (2016), who framed the grand challenge of sustainable electricity as their DSR problem statement, represents one exemplar. Other popular problem statements identified and described research gaps (25.0%) and research problems (16.3%). Further, 12.5 percent of the publications used requirements to frame their problem statements. For instance, Llansó, McNeil, Pearson, and Moore (2017) guided their design process with a list of nine requirements. We believe that requirement usage uniquely occurs in design science compared to behavioral science—possibly due to DSR's strong ties to computer science, where requirements often lead research (Kampling, Klesel, & Niehaves, 2016; Newell & Simon, 1976).

5.2 Research Question Formulation

Further, 61.5 percent of the publications defined at least one research question. However, many defined more than one research question. Figure 2 summarizes the distribution of publications with one, two, three, and four research questions. Conference papers tended to have a single research question, while *MISQ* papers and dissertations had more than one. These results support the view that a conference outlet represents a different genre of research publication and tend to be more focused and streamlined.

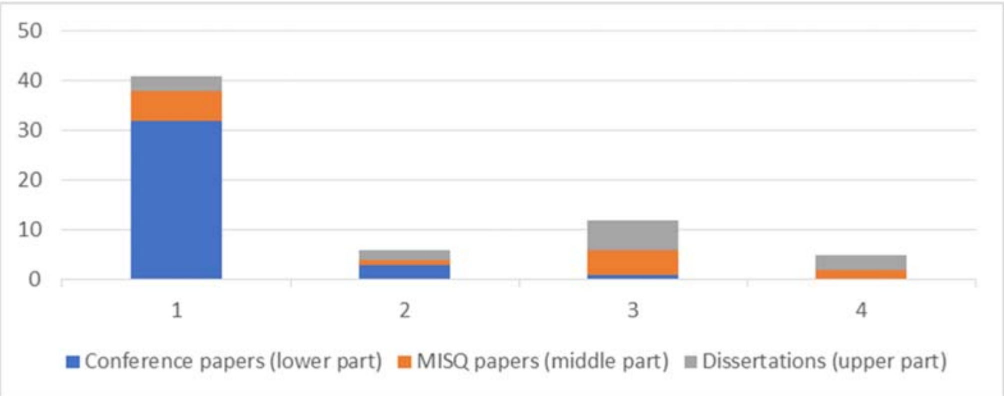

Figure 2. Number of Publications that Formulated One, Two, Three, and Four Research Questions

As for the type of research questions the papers formulated, the highest number (76.9%) formulated "how can we?" research questions that address the design process. This type of question emphasizes how one develops methods and procedures (Haj-Bolouri, Bernhardsson, & Rossi, 2016) and implements and operationalizes design artifacts (Mramba et al., 2016). A particularly high number of *MISQ* papers used this formulation, and several formulated more than one such question, which led to 27 process-related questions in 21 publications. For instance, Chou, Zahedi, and Zhao (2014) defined three process-related questions that guide their research (e.g., how can we process, how can we implement, and how can we evaluate).

The second highest number of papers formulated an artifact-related question (19.2%). This type of question emphasizes the DSR design product, which includes the "which components?" and "which properties?" questions that define the product (Thomas & Bostrom, 2010; Zoet, 2014).

A surprisingly small number of papers (2.9%) formulated a knowledge-related question. This type of question includes the "what is?" question that addresses prior and new knowledge related to the research. However, only dissertations formulated this type of question and addressed only prior knowledge (i.e., no paper addressed new knowledge). As for why we found such a result, researchers could have possibly treated knowledge as being beyond a research question's scope and preferred to address it in related work and in discussion/contribution sections.

Finally, in addition to these types of questions, we coded six publications in the "other" category, which emphasizes the notion that DSR studies can embed diverse inquiry modes and research methods (Baskerville et al., 2015), which these research questions' diverse formulations reflect.

Since we focus on how DSR researchers have constructed and formulated research questions in this paper, we cover and discuss the results in more detail in Sections 6 and 7.

5.3 Research Question Answer

As for the research approach that the studies we examined adopted, we found that exploratory research dominated (31.7%). We also observed a notable difference in the number of exploratory research papers between conference papers (38.1%) and both *MISQ* papers (19%) and dissertations (25%). This finding supports the view that the conference genre embraces emerging exploratory results, while journal papers and dissertations cover more mature research results. The next most popular approaches include those with prescriptive and constructive knowledge goals, which reflect the DSR methods and design principles that guide how one constructs artifacts.

As for the DSR activities the studies we examined adopted, we found that the highest number focused on building and/or evaluating. In particular, 51 percent of studies adopted developmental enquiry (51%), and 37.5 percent adopted a mixed (i.e., both developmental and evaluative) enquiry. We identified only four publications that adopted the evaluative mode, which suggests that, in design science, it may be difficult to report only on evaluation activities and that one may need to both build an artifact and evaluate it.

We identified a high number of publications that did not use any theory at all (45.2%). A recent literature survey (Thakurta, Müller, Ahlemann, & Hoffmann, 2017), which found that 46 percent of the DSR studies in their sample relied on argumentative deduction and not theories, also found that 26 percent of the studies relied on neither argumentative deductions nor theories, which supports our findings. When we omitted publications that did not use any theory, we found that 30.8 percent used kernel theories and 10.6 percent used formal theories to approach their research.

Finally, as for the outcome artifacts, instantiations and models appeared in 26.9 percent and 22.1 percent of the publications, respectively. Interestingly, 21.2 percent of the publications had more than two artifact outcomes. We subsequently mapped these DSR outcomes to the research question formulation. The results indicate that researchers usually derived instantiations and methods from process-related questions. We also observed that process-related questions could lead to paired artifacts, such as method and instantiation (Lee, Wyner, & Pentland, 2008) and model and instantiation (Lau et al., 2012). In addition, we found cases that generated three artifacts: method, model, and instantiation (Haj-Bolouri et al., 2016).

6 Constructing Research Questions in Design Science

In this section, we further our understanding about how DSR constructs research questions. As we discuss in Section 5.1, a research question in DSR comes in three basic types: problem solving, gap spotting, and problematization. We adopted Gregor and Hevner's (2013) framework and Sandberg and Alvesson's (2011) typology to further analyze the specific modes in these types of research question constructions.

We used the DSR knowledge contribution framework that Gregor and Hevner (2013) propose to analyze how DSR constructs problem-solving research questions because "constructing research questions and creating an opportunity for contribution are fairly close in the sense that a created space for contribution points to a specific question, and vice versa" (Sandberg & Alvesson, 2011, p. 26). Two dimensions form this framework: problem maturity and solution maturity. The combination of these dimensions defines four quadrants: routine design (known problem and known solution), improvement (known problem and new solution), exaptation (new problem and known solution), and invention (new problem and new solution). The first quadrant, which features well-defined problems and the solutions, rarely requires design science, so we omitted it from our analysis. The three other quadrants, which feature unknown problems and/or unknown solutions, represent areas for DSR, so we used them in our analysis.

We then used Sandberg and Alvesson's (2011) typology to analyze how DSR constructs gap-spotting and problematization research questions. With these scholars' typology, we could clearly categorize different ways of constructing gap-spotting and problematization research questions, which we summarize in Section

3. Gap spotting includes underresearched areas, overlooked areas that lack a specific focus, confusion, and areas that lack empirical support. Problematization includes in-house, root-metaphor, paradigm, ideology, and field assumptions.

Table 3 presents the three basic types of DSR research question construction and their specific modes, which we elaborate on below.

Table 3. Detailed Results for DSR Research Question Construction (N = 104)

Dimension	Value	Conference papers		*MISQ* papers		Dissertations		Total	
		N = 63	%	N = 21	%	N = 20	%	N = 104	%
Problem solving	Improvement	44	69.8%	13	61.9%	9	45.0%	66	63.5%
	Exaptation	7	11.1%	5	23.8%	2	10.0%	14	13.5%
	Invention	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Gap spotting	Underresearched	11	17.5%	1	4.8%	7	35.0%	19	18.3%
	Overlooked	3	4.8%	2	9.5%	4	20.0%	9	8.7%
	Lacking empirical support	7	11.1%	5	23.8%	2	10.0%	14	13.5%
Problematization	In-house assumptions	1	1.6%	1	4.8%	1	5.0%	3	2.9%
	Other problematization	0	0.0%	0	0.0%	0	0.0%	0	0.0%

6.1 Problem Solving

In our dataset, more papers adopted the problem-solving mode to construct DSR research questions compared to any other mode. The problem-solving mode focuses on identifying certain kinds of problems (e.g., practical problem, design problem, research problem, and research challenge) and on building solution artifacts that address them. The DSR research that adopts this construction usually mentions that "this research addresses the problem/challenge [ ]" (Ketter et al., 2016; Mramba et al., 2016). In the reviewed publications, we identify two problem-solving modes: improvement and exaptation.

The improvement mode focuses on building new solution artifacts for known problems. Half of the reviewed publications used the improvement mode; as such, it represented the most popular mode to construct DSR research questions. For example, Abbasi, Zhang, Zimbra, Chen, and Nunamaker (2010) used this mode to address the problem of detecting fake websites, a known application problem. This problem led the authors to construct research questions based on the argument that existing detecting systems had shortcomings that called for an improved solution with "a new class of fake website detection systems" (p. 436). They subsequently built the solution artifact and conducted a series of experiments that showed that these new solutions improved on the existing systems. Further, Adams (2013) and Mramba et al. (2016) also constructed DSR improvement research questions by proposing new solution artifacts for known problems.

In the improvement mode, the new solution artifacts vary. They can be instantiation artifacts, such as the fake website-detection system in the above example. They can also be solutions in the form of proposed constructs, methods, and models as improvements for an existing problem (Haj-Bolouri et al., 2016; Osterwalder, 2004). As an example of the latter, Osterwalder (2004) studied how one can better describe business models. He built his study on the argument that, due to their abstractness and vagueness, existing business models needed improvement. As such, he constructed the research question: "how can business models be described and represented in order to build the foundation for subsequent concepts and tools, possibly computer based?" (p. 2). Addressing this question, he built a set of artifacts, which included constructs, models, and instantiations, in his study.

The exaptation mode refers to constructing research questions that link artifacts in a field to a new problem context. We found that 13.5 percent of the reviewed publications used the exaptation mode. As an example, Larsen and Bong (2016) focused on the problem of detecting a construct identity, an emerging problem in large-scale literature reviews and meta-analyses. The authors addressed this problem by adapting and combining different natural language-processing algorithms. Therefore, they framed "this article as exaptation research: applying known solutions to new problems" (p. 530). Further, Braun, Schlieter, Burwitz, and Esswein (2016) and Lin, Chen, Brown, Li, and Yang (2017) also adapted solutions from a field to a new problem context.

Finally, none of the reviewed publications used the invention mode. This mode addresses radical breakthroughs where "little current understanding of the problem context exists and where no effective artifacts are available as solutions" (Gregor & Hevner, 2013, p. 345). We do not find this result surprising since true inventions are rare. Further, inventions need time to become established and recognized; researchers may, therefore, position them in their initial publications as either improvements or exaptations. Another explanation concerns the granularity with which one views the problem. Given a small enough problem space, one could consider almost all the solutions as inventions. On the other hand, given a large enough problem space, which could apply to the current case, one would notice very few inventions.

6.2 Gap Spotting

In our dataset, the second highest number of papers adopted the gap-spotting mode to construct DSR research questions. In contrast to the problem-solving mode where the research questions may come from practice, gap spotting focuses on identifying a gap in the literature and suggesting an artifact to bridge it. Publications that adopted this way of research question construction normally claim that "there is a gap in [ ]" (O'Leary, Mtenzi, & McAvinia, 2016) and "little research/guidelines exist for [ ]" (Parsons & Wand, 2008). In the reviewed publications, we identified three modes of gap spotting: underresearched, overlooked, and lacking empirical support.

Underresearched publications follow the line of reasoning that the literature contains a void that needs research attention. Nearly 20 percent of the reviewed publications used the underresearched mode. For example, focusing on classifying IS artifacts, Parsons and Wand (2008) built their research question on the argument that no well-grounded guidance for choosing IS modeling classes existed. The authors supported their argument by reviewing the literature and identifying the underresearched gap that "this literature primarily offers guidance or techniques for identifying candidate or potential classes for a domain, but does not offer grounded criteria for evaluating these possible classes…and choosing among them" (p. 842). As such, they built a model and a classification method to bridge the gap.

Similar to the underresearched mode, the overlooked mode also identifies a gap in the literature. However, they differ in that the overlooked mode searches for gaps in well-established areas that lack a specific focus. A typical overlooked argument would posit that the existing research area in a specific area requires an integrated view due to its fragmented nature. Nardi (2014) followed this approach by arguing that different application sections conceptualized the notion of service differently and, thus, that the literature required "a unified view of the notion of service" (p. 18). He subsequently constructed a common reference ontology of the service concept in order to bridge the overlooked gap.

The last gap-spotting mode in the reviewed publications concerns the lack of empirical support. This mode argues that existing research requires more empirical research due to its inconclusiveness. For example, Raber, Epple, Winter, and Rothenberger (2016), and Tagle and Felch (2016) adopted the gap-spotting mode in our dataset. Interestingly, several publications that used the lack of empirical support mode also used the problem-solving improvement mode. These DSR publications identified an empirical gap in the literature and bridged it by constructing solution artifacts and evaluating them (Adipat, Zhang, & Zhou, 2011; Thomas & Bostrom, 2010). The empirical results showed the usefulness of the solution artifacts (e.g., an improvement mode) and addressed the lack of empirical support (e.g., a lacking empirical support mode).

6.3 Problematization

The problematization mode refers to deficiencies in existing theories that require further research to remedy them. We found only three studies that adopted this mode, and they did so in a particular way: as an in-house assumption that challenged "a particular school of thought" (Alvesson & Sandberg, 2013, p. 52). These results concur with the ongoing calls for further theorizing in design science (Germonprez, Hovorka, & Collopy, 2007; Gregor & Jones, 2007). For example, Sahoo et al. (2012) conducted a study that exemplifies DSR problematization. They claimed that recommender systems usually rely on the assumption "that a user's preference is a static pattern" (p. 1331). They challenged this assumption in arguing that "users' product selection behaviors change over time" (p. 1329), which led them to propose a model for capturing a dynamic user's preference.

Overall, in this section, we present the basic ways in which DSR researchers have constructed research questions. Most papers used problem solving and/or gap spotting to construct their research questions, while only a few publications problematized underlying assumptions or theories to construct them. We extend Alvesson and Sandberg's (2011) typology in two aspects. First, we add problem solving to the typology as an additional way to construct DSR research questions. The reviewed publications used problem solving more than any other method to construct DSR research questions. Second, we confirm that the frequency with which DSR research uses gap spotting and problematization and the logic it uses to construct gap-spotting and problematization research questions resemble what one can find in management research (e.g., Sandberg & Alvesson, 2011). Nevertheless, DSR and management research involve different research activities. We found that DSR focuses on building and evaluating artifacts, whereas Sandberg and Alvesson (2011) found that management research focuses on building and testing theory.

7 Formulating Research Questions in Design Science

In this section, we explore how the studies in our sample formulated DSR research questions. As we discuss in Section 5, 64 of the 104 reviewed publications formulated at least one research question in the three basic types: "how?" (design process), "which?" (design product), and "what is?" (knowledge). We classify these research question types in more detail in Section 4.

Table 4. Detailed Results for DSR Research Question Formulation (N = 64)

Dimension	Value	Conference papers		*MISQ* papers		Dissertations		Total	
		N = 36	%	N = 14	%	N = 14	%	N = 64	%
How can we [ ]?	Process	13	36.1%	8	57.1%	6	42.9%	27	42.2%
	Use	6	16.7%	4	28.6%	9	64.3%	19	29.7%
	Evaluate	2	5.6%	10	71.4%	2	14.3%	14	21.9%
	Represent	6	16.7%	3	21.4%	1	7.1%	10	15.6%
	Implement	8	22.2%	2	14.3%	0	0.0%	10	15.6%
Which [ ] define?	Components	3	8.3%	2	14.3%	4	28.6%	9	14.1%
	Properties	0	0.0%	0	0.0%	7	50.0%	7	10.9%
	Requirements	0	0.0%	0	0.0%	4	28.6%	4	6.3%
What [ ] is available?	Prior knowledge	0	0.0%	0	0.0%	3	21.4%	3	4.7%
	New knowledge	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Other		3	8.3%	2	14.3%	1	7.1%	6	9.4%

7.1 How?

The publications in our sample overwhelmingly used "how can we [ ]?" questions to formulate their DSR research questions, which emphasizes DSR design process outcome. In particular, we identified five categories for these questions: process, use, evaluate, represent, and implement. The highest number of papers (42.2%) in the sample used "how can we process?" questions. Studies in this category focused on developing methods and procedures and the design principles for the procedures. Publications also commonly used "how can we use?" questions: they appeared in 29.7 percent of the publications. Studies in this category operationalized and used design artifacts to address identified problems. Studies that used "how can we [ ]" questions in the remaining categories (represent, implement, and evaluate) focused on developing a model in a domain of interest, implementing the instantiation, and determining specific artifacts' utility.

7.2 Which?

We found many publications that used "which [ ] define?" questions, which emphasize the DSR design process outcome. In particular, we identified three categories for these questions: components, properties, and requirements. Specifically, we found that questions in each category appeared in nine, seven, and four publications, respectively. While all the studies examined the outcome artifacts, these questions focused on different design stages—from defining requirements and specifying properties to developing artifact components.

7.3 What is?

We found few publications that used "what [ ] is available" questions, which emphasize knowledge contributions. We identified two categories for these questions: prior knowledge and new knowledge. While three reviewed publications adhered to the prior knowledge category, none adhered to the new knowledge category. Even though these results could suggest that we should disregard these genres as irrelevant, we nevertheless believe that DSR should consider them. We argue that DSR implicitly involves these types of questions since it should demonstrate adequate use of the existing knowledge base and also demonstrate distinct knowledge contributions (Gregor & Hevner, 2013). Therefore, we suggest that researchers should make these questions more explicit and integrate them fully in their DSR publications.

Overall, we identified ten basic forms in which researchers have formulated their DSR research questions (i.e., "what prior knowledge is available?", "how can we process?", "how can we use?", "how can we evaluate?", "how can we represent?', "how can we implement?", "which components define?", "which properties define?", "which requirements define?", and "what new knowledge is available?"). However, one needs to combine these basic question forms with actual substance (such as project and context-specific constructs or artifacts) to create actual and complete DSR research questions. Future DSR projects can draw on these basic forms to develop research questions across the range of DSR genres and combine them with project and context-specific artifacts.

7.4 Typology of DSR Research Questions

To further support the DSR research question formulation, we provide a typology that describes how DSR researchers have expressed research questions. We present the typology not to constrain DSR researchers to a set of rules on the "right" research questions but as a foundation that they can use to formulate and express them. While one can adopt different approaches to build a typology, we followed Bailey (1994) and adopted the conceptual-to-empirical approach. This approach starts with a conceptual typology structure and subsequently uses it to examine the empirical cases for building profiles of each typological element.

In the conceptual activity, we developed a structure that frames the question genres that Table 4 identifies. Figure 3 shows the hierarchical typology that resulted. It distinguishes different ways of doing DSR research, related research question articulations, and their specific concerns.

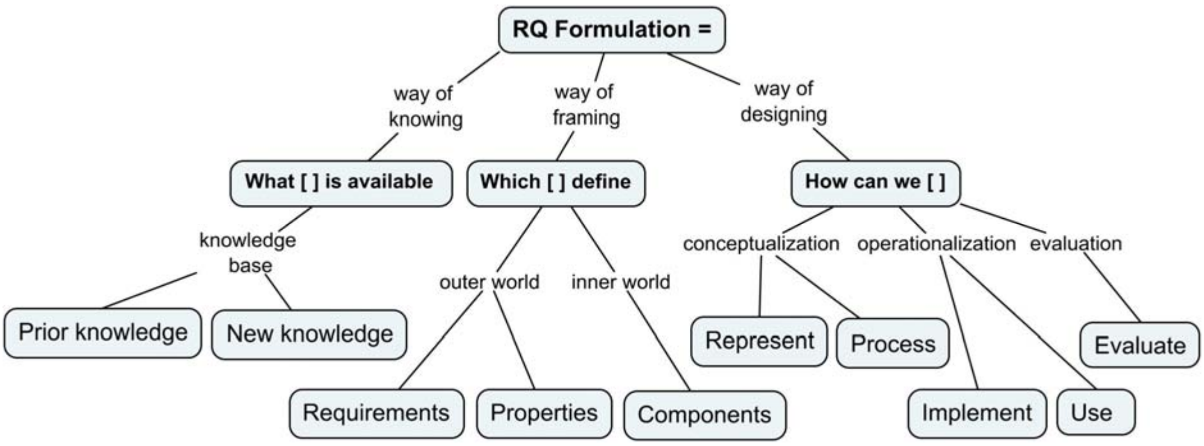

Figure 3. Typology of DSR Research Questions

The top of this typology classifies three different ways of doing research: way of knowing, way of framing, and way of designing. These categories respectively address the acquisition and generation of knowledge about artifacts (Gregor & Hevner, 2013), the frame for what one has to design (i.e., the object of attention (Schön, 1984)), and the consideration of how to design the artifacts (Hevner et al., 2004; Peffers et al., 2007). Each category leads towards a specific research question articulation.

The way of knowing leads to "what [ ] is available?" questions, which direct inquiries about the knowledge base. These questions seek to answer what one knows before research and what new knowledge one will know after it. While we found only a few publications that explicitly formulated these questions, we also found that many publications implicitly addressed both the prior knowledge and the contributed knowledge in their foundational and the discussion sections. Given the importance of these research questions and the wide range of knowledge they could contribute to DSR, our typology suggests moving from implicitness to explicitness. In other words, these research questions can serve as a helpful tool to explicitly scaffold links between research and the knowledge base.

The way of framing leads to “which [ ] define?” questions, which characterize an artifact as the object of attention. To further distinguish these questions, we adopt Simon’s (1996) distinction between inner and outer worlds. The inner world concerns an artifact’s internal structure (i.e., the components put together to materialize the artifact). The outer world concerns the requirements and properties that constrain an artifact’s existence or usefulness. Requirements normally prescribe properties to which an artifact has to conform. Requirements closely relate to the artifact’s uses, while properties relate more to its identity.

Finally, the way of designing leads to “how can we [ ]?” questions, which concern the activities required to realize an artifact. According to Table 4, these questions represent the most common ones. We further divide these questions based on three concerns. First, one has to conceptualize the artifact, which concerns both the artifact representation (“how can we represent?”) and the activities necessary to achieve it (“how can we process?”) since they reflect design’s complementary perspectives as a noun and a verb (Gregor & Jones, 2007). Second, one has to operationalize the artifact. Implementation (“how can we implement?”) and use (“how can we use?”) represent two complementary aspects of operationalization. Finally, since design always involves some type of evaluation, one also has to consider this aspect in the design approach, which leads to “how can we evaluate?” questions.

Overall, this typology helps researchers to formulate DSR research questions. It narrows down the abstract ways of doing DSR to specific questions that logically express specific areas of concern. Furthermore, given the predominant developmental mode of inquiry, this typology also suggests ways of structuring DSR research by using multiple research questions that address the ways of knowing, framing, and designing.

To complete the typology, we next built the empirical profile for each question form. To this end, we grouped the research questions that we identified in the literature according to the typology of DSR questions. We conducted a pattern matching analysis of each question form (Yin, 2013). We looked for similarities and differences between the question forms so we could identify common patterns and terms among them. Table 5 summarizes the results and also includes the “what new knowledge is available?” question that we did not found evidence for in our sample. We extrapolate the suggested patterns for this particular question from how publications used the “what prior knowledge is available?” question.

Table 5 proposes DSR research question forms and shows patterns associated with them. Note that Table 5 and Figure 3 complement each other: the table shows how empirical patterns that we identified in the reviewed sample of publications fit the conceptualization in the typology (Figure 3)[1]. Therefore, we suggest that one should use them together. DSR researchers can relate their research to the typology to identify appropriate research questions and to draw on the suggested patterns to actually formulate their questions. By considering the way of knowing, way of framing, and way of designing, researchers could use a set of questions to start and scope a DSR project. However, the DSR project will probably evolve over time. As such, we also need to understand how researchers can use the typology to provide a set of consistent questions that support DSR projects’ evolution, which we focus on in Section 7.5.

[1] With the exception of “what new knowledge is available?” as we mention in the previous paragraph.

Table 5. Profile of DSR Research Questions

Question form	Suggested patterns
What prior knowledge is available?	What current understanding of X is addressed? What current knowledge about X is available? How can an understanding of X be achieved?
What new knowledge is available?	What new understanding of X can be achieved? What new knowledge does X contribute?
Which components define?	What are the essential components of X? Which components define X? What components should X include?
Which properties define?	Which properties characterize X? Which are the important properties of X? What are the commonalities of X? What would characterize X?
Which requirements define?	Which requirements define X?
How can we represent?	How can we model X? How can we represent the elements of X? How can X's elements be combined in model Y? What typifies X's ontology?
How can we process?	How can we conduct X? How can we elaborate X? What is a suitable way of doing X? Which strategy can be used for X?
How can we use?	How can we use X? How can we operationalize X? How can we apply X? How should X be utilized?
How can we implement?	How can we implement X? How can we develop X? Can X be implemented?
How can we evaluate?	How can we evaluate X? What evaluation measures can be used to assess X? In what way can X be improved?

7.5 Using the Typology in Hevner's DSR Cycles

This section illustrates how the typology can align with DSR projects' progress. According to Hevner (2007), DSR projects progress through three cycles: relevance, design, and rigor. The relevance cycle links the application domain with the DSR effort, which suggests the requirements and, specifically, requires one to apply the artifact to the application domain in order to validate its practical usage. The design cycle iterates between two DSR activities: building and evaluating. Finally, the rigor cycle grounds the other cycles on the existing knowledge base and, due to the research activities, mandates that one should add new knowledge to the knowledge base.

To demonstrate how the typology can fit a DSR project's progress, we map the DSR research question genres to the three cycles (see Figure 4). We also add a sequence that follows the logical progress through the cycles to these research questions.

At the beginning, the DSR project explores the target artifact's requirements that one has obtained from the application domain (Hevner, 2007). Thus, at this stage, one asks: "which requirements define the artifact?". The requirements' exploration should begin with the outer world (i.e., the requirements) and then consider the inner world (i.e., the artifact's properties and components). Given the list of requirements, the DSR project then moves to the building activity. One can formulate different questions in this activity, such as "how can we represent the artifact?", "how can we process the artifact?", and "how can we implement the artifact?". As for the building activity, the DSR project also needs to define the artifact's knowledge foundation by asking "what prior knowledge is available about artifact X, which can be grounded on the knowledge base (KB)?".

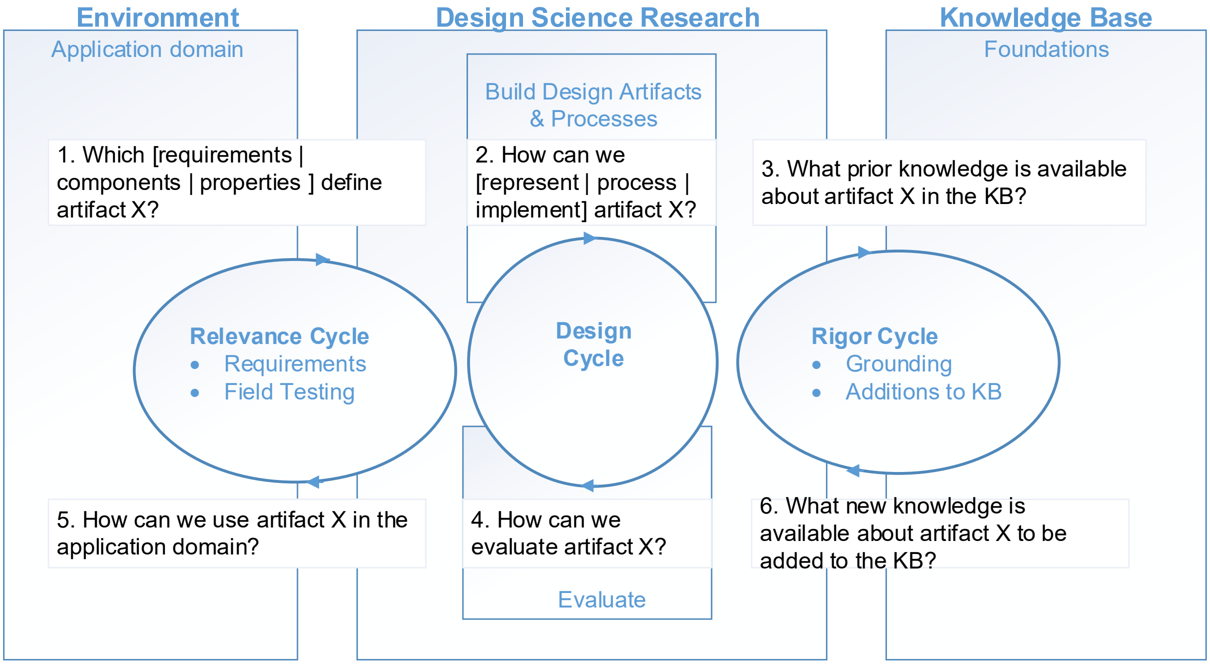

Figure 4. Positioning the DSR Genres in Hevner's Three-cycle View (Adapted from Hevner, 2007)

After the building activity, the DSR project moves to the evaluating activity and formulates "how can we evaluate the built artifact?". Thereafter, the DSR project returns the artifact to the application domain, which poses the next question: "how can we use the artifact in the application domain?". Addressing all of the above questions may generate new knowledge about not only the artifact's innovativeness but also the methods adopted to develop the artifact or the application domain. Since knowledge contributions play a key role in communicating a DSR project's outcomes to an academic audience (Hevner & Chatterjee, 2010), we suggest that DSR should explicitly address the question "what new knowledge is available about the artifact and the context that can be added to the knowledge base?".

Overall, we suggest that the different genres in the typology enable DSR researchers to articulate specific research questions throughout a DSR project. As the project evolves, the typology can help formulate the next set of research questions for each cycle. Furthermore, we also suggest that DSR research questions are not static constructs during DSR projects but evolve dynamically throughout them (i.e., researchers update and change the research questions as the project enfolds). Reflecting this dynamic, we suggest that researchers should use the typology as an open frame that informs basic DSR genres and accepts new DSR genres.

We now derive practical guidance for DSR researchers on how to formulate research questions in DSR projects. In Table 6, we provide basic templates that they can use to formulate research questions to develop common artifacts: construct, model, method, and instantiation. We suggest a set of research questions for each artifact type. We begin with the relevance cycle and move to the design cycle and the rigor cycle. A DSR project may draw on only a part of the template, may draw on different parts of the template, may add other research questions, and may combine these templates when the project focuses on developing multiple artifacts. We emphasize DSR research's diversity and openness if researchers can pose different research questions about a specific artifact. Table 6 shows how the profiles fit such diversity.

Table 6. Templates for DSR Research: Research Question Formulation and Corresponding Expressions

Goal	Suggested template
Develop model	**Which** *requirements* define the [model]? **What** *prior knowledge* is available about the [model]? **What are** the [model]'s essential *components*? **How can we** *represent* the [model]? **How can we** *evaluate* the [model]? **What** *new knowledge* does the [model] contribute?
Develop method	**What are** the essential *requirements* for designing the [method]? **Which** essential *properties* characterize the [method]? **What** *prior knowledge* is available about the [method]? **How can we** elaborate (*process*) the [method] to be compliant with the set of [requirements, properties]? **How can we** *implement* the [method]? **How can we** *evaluate* the [method]? **How can we** *use* the [method]? **What** *new knowledge* does the [method] contribute?
Develop construct	**Which** essential *properties* characterize the [construct]? **What** *prior knowledge* is available about the [construct]? **How can we** *represent* the [construct]? **How can we** *operationalize* the [construct]? **How can we** *use* the [construct]? **What** *new knowledge* does the [construct] contribute?
Develop instantiation	**What are** the essential *requirements* for designing the [instantiation]? **Which** essential *properties* characterize the [instantiation]? **Which** essential *components* constitute the [instantiation]? **How can we** *represent* the [data, functional, behavioral…] structure of the [instantiation]? **How can we** elaborate a *process* to design an [instantiation] compliant with the set of defined [requirements, properties, components]? **How can we** *implement* an [instantiation] that operationalizes the set of [requirements, properties, components]? **What** *prior knowledge* is available about the [instantiation]? **How can we** *evaluate* the [instantiation]? **How can we** *use* the [instantiation]? **What** *new knowledge* does the [instantiation] contribute?
Note: To increase readability of Table 6, we present the research question forms in bold font, the areas of concerns in italics, and the substances or artifacts in [ ].	

8 Discussion

Given the DSR paradigm's distinct nature, we conceptually and empirically investigate how DSR publications have constructed and formulated their research questions. Nunamaker et al. (1990) and Hevner and Chatterjee (2010) state that future DSR publications should state their research questions clearly. Clear research questions help DSR projects define their focus, drive the research approach, and position the research contributions. In analyzing the research questions of 104 DSR publications, we found that nearly two-thirds (61.5%) explicitly used research questions in order to link the problem statements to the chosen research approaches. Consequently, we highlight and reinforce the role of research questions in DSR, which allows future DSR research questions to match the importance of research questions in the IS discipline (Dubé & Paré, 2003; Recker, 2012; Venkatesh et al., 2013). We further provide DSR researchers with additional guidance and, thus, help researchers to fully exploit the knowledge their DSR projects can contribute in their publications.

DSR differs from other research paradigms in that it predominantly uses problem solving to construct research questions (see Section 6). This finding not only further validates DSR's problem-solving nature (Hevner et al., 2004; Nielsen & Persson, 2016) but also underlines the need for a unique way to formulate research questions that suit problem solving. We also point out that existing DSR publications have underused problematization in which one constructs research questions by challenging the existing theoretical status quo beyond "superficially" spotting gaps or identifying real-world problems. As such, we encourage design-oriented researchers to incorporate problematization into their repertoire, which will provide deeper and richer knowledge contributions beyond developing innovative and useful artifacts.

DSR also differs from other research paradigms because its research questions can reflect a predominantly developmental approach to research. We found many studies that adopted multiple, logically related research questions that ranged from the way of knowing to the way of framing and the way of designing (see Figure 3). To further highlight DSR's contribution to the knowledge base beyond artifacts, we suggest including a particular question—"what new knowledge is available?"—that we could not find evidence for in the literature review. We envisage DSR studies structured in such a way that they combine the "what prior knowledge is available?" question with the "which [ ] define?", "how can we [ ]?", and "what new knowledge is available?" questions. This way, researchers can scaffold the whole knowledge-generating research process—not just the design-oriented part—via using research questions.

We also found differences in how publications constructed research questions depending on their genre. Problem-solving dominated the journal and conference papers (83.3%) but not the dissertations (55%). In a similar vein, the way of designing dominated the journal and conference papers but not the dissertations. For the journal and conference papers, 62 questions pursued the way of designing (versus five questions that pursued the way of knowing and way of framing). The proportion was more balanced for the dissertations (18 questions that pursued the way of designing versus 18 questions that pursued the way of knowing and the way of framing). On the whole, the combination of problem solving and the way of designing suggests that DSR papers tend to emphasize pragmatism. We need more research to understand why DSR papers seem to devalue the way of knowing and the way of framing in their research question construction.

When examining the approaches to answering DSR research questions, we identified three interesting points. First, the publications predominantly used the developmental mode to answer DSR research questions (53% for developmental and 39% for developmental and evaluative combined). This result concurs with the high number of "how can we [ ]?" and "which [ ] define?" questions we found in the publications. Second, we identified a high number of publications without theory in use, which also concurs with their emphasis on problem solving rather than on gap spotting or problematization. Finally, we found that the publications most frequently developed model and instantiation artifacts, which concurs with another recent study's findings (Thakurta et al., 2017). We can see these three approaches as mutually reinforcing and internally consistent.

To help formulate research questions and improve what their answers can contribute to DSR, we provide a set of forms for DSR research questions (Table 4), their profiles (Table 5), their evolution over DSR research's progress (Figure 4), and templates for common research projects (Table 6). On the one hand, these forms, profiles, and templates reveal DSR's diverse and dynamic nature, which contributes to positioning design science as a distinctive research paradigm (Rai, 2017). On the other hand, these aspects also reveal the territory that design science claims in terms of research practice. Moreover, they provide hints that future DSR should either consolidate or expand its territory.

We also propose a typology that highlights how DSR formulates research questions. We hope that this typology will inspire DSR researchers to interpret, position, and structure their future research and their intended contributions. We suggest that researchers should use the typology dynamically. In particular, the combination of the typology and Hevner's (2007) three cycles allows researchers to identify "what the next research question is" over a DSR project's course. In this respect, DSR researchers can use the typology's basic forms, templates, and profiles to formulate the identified research questions. We reiterate that we do not regard our research question genres, profiles, and templates as mandatory for DSR researchers.

In addition, research questions that one constructs at the beginning of a DSR endeavor need not remain invariant over time and, thus, limit the design and inquiry's scope. We understand that research questions may change during a DSR project, such as in our own research. We started with the initial question "how can we construct research questions in line with the DSR paradigm's nature and purpose?", which we can now split into four questions: 1) "what prior knowledge is available about DSR research questions?", 2) "how can we represent research questions that are in line with the DSR paradigm's nature and purpose?", 3) "which components define research questions that are in line with the DSR paradigm's nature and purpose?", and 4) "what new knowledge is available about DSR research questions?". These changes, again, fit the use of the research question types in Hevner's (2007) cycles.

We hope that our investigations' results will guide and inspire DSR researchers to use research questions to help ensure that their research has a solid foundation (through problem solving, gap spotting, or problematization). In addition, research questions can help researchers consider the scope of their design and corresponding inquiry comprehensively to allow them to maximize their research contributions and their impacts. These recommendations apply at the outset of a new DSR endeavor and over its duration whenever the evaluation results call for one to reconsider the artifacts beyond incremental redesigns or even for an entirely new research direction.

9 Conclusion

In this paper, we analyze the existing DSR literature to understand how DSR publications construct and formulate their research questions. We identify ways of constructing research questions and define particular question forms, which can help researchers better understand prior research and construct their own research questions. We provide further guidance through a typology of research questions that addresses common patterns to express research questions during a DSR project's progress. Although other researchers have already presented several principles for conducting and presenting DSR (Gregor & Hevner, 2013; Hevner & Chatterjee, 2010), our study provides specific guidelines on how to construct DSR research questions.

However, our research has several limitations that readers should consider. First, research questions have a key role in communicating research after one has concluded a project. As such, one should interpret our findings in light of what one expects DSR to deliver at the end of a project. In addition, one should not overrationalize a research project at its very beginning. Second, our findings pertain to research questions that DSR publications explicitly reported, which means that we may have missed implicit research questions. Nevertheless, other researchers have successfully examined research questions that academic publications document (Hällgren, 2012; Sandberg & Alvesson, 2011). Third, while we propose a typology based on empirical analyzing 104 DSR publications, we need to further evaluate it. As Prat, Comyn-Wattiau, and Akoka (2015) suggest, we plan to conduct both a formative and a summative evaluation in the future. Fourth, while our sample has a reasonable size, we could extend the sample to include more dissertations, journals, and conferences, which would increase the generalizability of the research results. We plan to do so in future work. Finally, even though the topic that this research addresses relates to research philosophy and epistemology, we have not yet explored it from these perspectives.

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Zoet, M. (2014). *Methods and concepts for business rules management* (doctoral dissertation). Utrecht University, the Netherlands.

Appendix A

Table A1. List of Reviewed Publications

No	Reference
Mature publications (MIS papers)	
1	Abbasi, A., & Chen, H. (2008). CyberGate: A design framework and system for text analysis of computer-mediated communication. *MIS Quarterly*, *32*(4), 811-837.
2	Abbasi, A., Albrecht, C., Vance, A., & Hansen, J. (2012). MetaFraud: A meta-learning framework for detecting financial fraud. *MIS Quarterly*, *36*(4), 1293-1327.
3	Abbasi, A., Zhang, Z., Zimbra, D., Chen, H., & Nunamaker, J. (2010). Detecting fake websites: The contribution of statistical learning theory. *MIS Quarterly*, *34*(3), 435-461.
4	Adipat, B., Zhang, D., & Zhou, L. (2011). The effects of tree-view based presentation adaptation on model Web browsing. *MIS Quarterly*, *35*(1), 99-121.
5	Adomavicius, G., Bockstedt, J., Gupta, A., & Kauffman, R. (2008). Making sense of technology trends in the information technology landscape: A design science approach. *MIS Quarterly*, *32*(4), 779-809.
6	Chen, R., Sharman, R., Rao, R., & Upadhyaya, S. (2013). Data model development for fire related extreme events: An activity theory approach. *MIS Quarterly*, *37*(1), 125-147.
7	Chou, C.-H., Zahedi, F., & Zhao, H. (2014). Ontology-based evaluation of natural disaster management websites: A multistakeholder perspective. *MIS Quarterly*, *38*(4), 997-1016.
8	Ketter, W., Peters, M., Collins, J., & Gupta, A. (2016). A multiagent competitive gaming platform to address societal challenges. *MIS Quarterly*, *40*(2), 447-460.
9	Larsen, K., & Bong, C. H. (2016). A tool for addressing construct identity in literature reviews and metaanalyses. *MIS Quarterly*, *40*(3), 529-551.
10	Lau, R., Liao, S., Wong, K. F., & Chiu, D. (2012). Web 2.0 environmental scanning and adaptive decision support for business mergers and acquisitions. *MIS Quarterly*, *36*(4), 1239-1268.
11	Lee, J., Wyner, G., & Pentland, B. (2008). Process grammar as a tool for business process design. *MIS Quarterly*, *32*(4), 757-778.
12	Lin, Y.-K., Chen, H., Brown, R. A., Li, S.-H., & Yang, H.-J. (2017). Healthcare predictive analytics for risk profiling in chronic care: A Bayesian multitask learning approach. *MIS Quarterly*, *41*(2), 473-495.
13	McLaren, T., Head, M., Yuan, Y., & Chan, Y. (2011). A multilevel model for measuring fit between a firm's competitive strategies and information systems capabilities. *MIS Quarterly*, *35*(4), 909-929.
14	Parsons, J., & Wand, Y. (2008). Using cognitive principles to guide classification in information systems modeling. *MIS Quarterly*, *32*(4), 839-868.
15	Pries-Heje, J., & Baskerville, R. L. (2008). The design theory nexus. *MIS Quarterly*, *32*(4), 731-755.
16	Reinecke, K., & Bernstein, A. (2013). Knowing what a user likes: A design science approach to interfaces that automatically adapt to culture. *MIS Quarterly*, *37*(2), 427-453.
17	Sahoo, N., singh, param vir, & Mukhopadhyay, T. (2012). A hidden Markov model for collaborative filtering. *MIS Quarterly*, *36*(4), 1329-1356.
18	Thomas, D., & Bostrom, R. (2010). Vital signs for virtual teams: An empirically developed trigger model for technology adaptation interventions. *MIS Quarterly*, *34*(1), 115-142.
19	Vance, A., Lowry, P. B., & Eggett, D. (2015). Increasing accountability through user-interface design artifacts: A new approach to addressing the problem of access-policy violations. *MIS Quarterly*, *39*(2), 345-366.
20	VanderMeer, D., Dutta, K., & Datta, A. (2012). A cost-based database request distribution technique for online e-commerce applications. *MIS Quarterly*, *36*(2), 479-507.
21	Venkatesh, V., Aloysius, J. A., Hoehle, H., & Burton, S. (2017). Design and evaluation of auto-ID enabled shopping assistance artifacts in customers' mobile phones: Two retail store laboratory experiments. *MIS Quarterly*, *41*(1).
Extensive publications (doctoral dissertations)	
22	Adams, R., (2012). *The advanced data acquisition model (ADAM): A process model for digital forensic practice* (doctoral dissertation). Murdoch University.
23	Bauer, A., (2016). *Information filtering in high velocity text streams using limited memory: An event-driven approach to text stream analysis* (doctoral dissertation). University of Regensburg.

Table A1. List of Reviewed Publications

24	Ducrou, A. J. (2009). *Complete interoperability in healthcare: Technical, semantic and process interoperability through ontology mapping and distributed enterprise integration techniques* (doctoral dissertation). University of Wollongong.
25	Finney, K. T. (2012). *Ontology management and selection in re-use scenarios* (doctoral dissertation). University of Tasmania.
26	Fumarola, M. (2011). *Multiple worlds: A multi-actor simulation-based design method for logistics systems* (doctoral dissertation). Delft University of Technology.
27	Hanid, M. B. (2014). Design science research as an approach to develop conceptual solutions for improving cost management in construction (doctoral dissertation). University of Salford.
28	Künzle, V. (2013). *Object-aware process management* (doctoral dissertation). University of Ulm.
29	Löfström, T. (2015). On effectively creating ensembles of classifiers: Studies on creation strategies, diversity and predicting with confidence (doctoral dissertation). Stockholm University.
30	Marques, R. P. F. (2014). *Organisational transactions with embedded control* (doctoral dissertation). University of Minho.
31	Nardi, J. C. (2014). *A commitment-based reference ontology for service: Harmonizing service perspectives* (doctoral dissertation). Federal University of Espírito Santo.
32	Niedermann, F. (2015). *Deep business optimization: Concepts and architecture for an analytical business process optimization platform* (doctoral dissertation). University of Stuttgart.
33	Osterwalder, A. (2004). The business model ontology: A proposition in a design science approach (Doctoral dissertation, University of Lausanne).
34	Pigott, D. (2012). A *perspective and framework for the conceptual modelling of knowledge* (doctoral dissertation). Murdoch University.
35	Sapateiro, C. M. G. L. D. (2013). *Evaluating mobile collaborative applications support of teamwork in critical incidents response management* (doctoral dissertation). University of Lisbon.
36	Scherer, S. (2016). *Towards an e-participation architecture framework (EPArt-framework)* (doctoral dissertation). University of Koblenz-Landau.
37	Simoes, D. (2016). *An end-user approach to business process modelling* (doctoral dissertation). University of Lisbon.
38	Vanderfeesten, I. (2009). *Product-based design and support of workflow processes* (doctoral dissertation). Eindhoven University of Technology.
39	Viberg, O. (2015). *Design and use of mobile technology in distance language education: Matching learning practices with technologies-in-practice* (doctoral dissertation). Örebro University.
40	Wikström, R. (2014). *Fuzzy ontology for knowledge mobilisation and decision support* (doctoral dissertation). Åbo Akademi University.
41	Zoet, M. M. (2014). *Methods and concepts for business rules management* (doctoral dissertation). Utrecht University.
Emerging publications (conference papers)	
42	Akoka, J., Comyn-Wattiau, I., Prat, N., & Storey, V. C. (2017). Evaluating knowledge types in design science research: An integrated framework. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 201-217). Cham, Switzerland: Springer.
43	Alharbi, O., & Chatterjee, S. (2016). Design of an awareness smartphone platform based on direct and indirect persuasion for energy conservation. In *Proceedings of the 11th International Conference on Tackling Society's Grand Challenges with Design Science* (LNCS vol. 9661, pp. 3-18). Cham, Switzerland: Springer.
44	Alharbi, O., & Chatterjee, S. (2017). GreenCrowd: An IoT-based smartphone app for residential electricity conservation. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 348-363). Cham, Switzerland: Springer.
45	Alismail, S., Zhang, H., & Chatterjee, S. (2017). A framework for identifying design science research objectives for building and evaluating IT artifacts. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 218-230). Cham, Switzerland: Springer.

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46	Aljaroodi, H. M., Adam, M. T. P., Chiong, R., Cornforth, D. J., & Minichiello, M. (2017). Empathic avatars in stroke rehabilitation: A co-designed mhealth artifact for stroke survivors. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 73-89). Cham, Switzerland: Springer.
47	Barquet, A. P., Wessel, L., & Rothe, H. (2017). Knowledge accumulation in design-oriented research. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 398-413). Cham, Switzerland: Springer.
48	Baskerville, R., & Vaishnavi, V. (2016). Pre-theory design frameworks and design theorizing. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 4464-4473)
49	Blaschke, M., Haki, M. K., Riss, U., & Aier, S. (2017). Design principles for business-model-based management methods—a service-dominant logic perspective. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 179-198). Cham, Switzerland: Springer.
50	Bonazzi, R., Cimmino, F., & Blondon, K. (2017). Healthy lottery: An economically viable mobile system to increase compliance of individuals with diabetes. In *Proceedings of the 50th Hawaii International Conference on System Sciences* (pp. 1463-1472).
51	Braun, R., Schlieter, H., Burwitz, M., & Esswein, W. (2016). BPMN4CP revised—extending BPMN for multi-perspective modeling of clinical pathways. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 3249-3258).
52	Braunnagel, D., & Leist, S. (2016). Applying evaluations while building the artifact—experiences from the development of process model complexity metrics. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 4424-4433).
53	Comes, T., & Schwabe, G. (2016). From fuzzy exploration to transparent advice: Insights into mobile advisory services. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 1256-1265).
54	Contell, J. P., Díaz, O., & Venable, J. R. (2017). DScaffolding: A tool to support learning and conducting design science research. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 441-446). Cham, Switzerland: Springer.
55	Czarnecki, C., & Dietze, C. (2017). Domain-specific reference modeling in the telecommunications industry. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 313-329). Cham, Switzerland: Springer.
56	Dellermann, D., Lipusch, N., & Ebel, P. (2017). Developing design principles for a crowd-based business model validation system. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 163-178). Cham, Switzerland: Springer.
57	Díaz, O., Contell, J. P., & Venable, J. R. (2017). Strategic reading in design science: Let root-cause analysis guide your readings. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 231-246). Cham, Switzerland: Springer.
58	Eryilmaz, E., Thoms, B., Mary, J., Kim, R., & Canelon, J. (2016). Task Oriented Reading of Instructional Materials and Its Relationship to Message Scores in Online Learning Conversations. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 2105-2114).
59	Farrelly, R., & Chew, E. (2016). Designing a personal information transaction object. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 4062-4071).
60	Feldotto, M., John, T., Kundisch, D., Hemsen, P., Klingsieck, K., & Skopalik, A. (2017). Making gamification easy for the professor: Decoupling game and content with the StudyNow mobile app. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 462-467). Cham, Switzerland: Springer.
61	Fill, H.-G., Pittl, B., & Honegger, G. (2017). A Modeling environment for visual SWRL rules based on the SeMFIS platform. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 452-456). Cham, Switzerland: Springer.
62	Fischer, M., Heim, D., Janiesch, C., & Winkelmann, A. (2017). Assessing process fit in ERP implementation projects: A methodological approach. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 3-20). Cham, Switzerland: Springer.
63	Forsgren, N., Tremblay, M. C., VanderMeer, D., & Humble, J. (2017). DORA platform: DevOps assessment and benchmarking. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 436-440). Cham, Switzerland: Springer.

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64	Fuchsberger, A. (2016). Improving decision making skills through business simulation gaming and expert systems. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 827-836).
65	Glöckner, M., Niehoff, T., Gaunitz, B., & Ludwig, A. (2017). Logistics service map prototype. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 431-435). Cham, Switzerland: Springer.
66	Goldkuhl, G., Ågerfalk, P., & Sjöström, J. (2017). A design science approach to information systems education. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 383-397). Cham, Switzerland: Springer.
67	Gruenen, J., Bode, C., & Hoehle, H. (2017). Predictive procurement insights: B2B business network contribution to predictive insights in the procurement process following a design science research approach. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 267-281). Cham, Switzerland: Springer.
68	Haj-Bolouri, A., Bernhardsson, L., & Rossi, M. (2016). PADRE: A method for participatory action design research. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 9661, pp. 19-36). Cham, Switzerland: Springer.
69	Hake, P., Fettke, P., Neumann, G., & Loos, P. (2017). Extracting business objects and activities from labels of german process models. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 21-38). Cham, Switzerland: Springer.
70	Hansen, M. R. P., & Pries-Heje, J. (2016). Out of the bottle: Design principles for GENIE tools (group-focused engagement and network innovation environment). In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 9661, pp. 131-146). Cham, Switzerland: Springer.
71	Jannaber, S., Riehle, D. M., Delfmann, P., Thomas, O., & Becker, J. (2017). Designing a framework for the development of domain-specific process modelling languages. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 39-54). Cham, Switzerland: Springer.
72	Kilic, M., Dolata, M., & Schwabe, G. (2017). Why do you ask all those questions? Supporting client profiling in financial service encounters. In *Proceedings of the 50th Hawaii International Conference on System Sciences* (pp. 4695-4704).
73	Kloker, S., Straub, T., & Weinhardt, C. (2017). Designing a crowd forecasting tool to combine prediction markets and real-time Delphi. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 468-473). Cham, Switzerland: Springer.
74	Knierim, M. T., Jung, D., Dorner, V., & Weinhardt, C. (2017). Designing live biofeedback for groups to support emotion management in digital collaboration. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 479-484). Cham, Switzerland: Springer.
75	Koukal, A., & Piel, J.-H. (2017). Financial decision support system for wind energy—analysis of Mexican projects and a support scheme Concept. In *Proceedings of the 50th Hawaii International Conference on System Sciences* (pp. 972-981).
76	Kowatsch, T., Volland, D., Shih, I., Rüegger, D., Künzler, F., Barata, F., Filler, A., Büchter, D., Brogle, B., Heldt, K., Gindrat., P., Farpour-Lambert, N., & l'Allemand, D. (2017). Design and evaluation of a mobile chat app for the open source behavioral health intervention platform MobileCoach. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 485-489). Cham, Switzerland: Springer.
77	Kramer, T., Heinzl, A., & Neben, T. (2017). Cross-organizational software development: Design and evaluation of a decision support system for software component outsourcing. In *Proceedings of the 50th Hawaii International Conference on System Sciences.*
78	Kruse, L. C., Seidel, S., & Purao, S. (2016). Making use of design principles. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 9661, pp. 37-51). Cham, Switzerland: Springer.
79	Llanso, T., McNeil, M., Pearson, D., & Moore, G. (2017). BluGen: An analytic framework for mission-cyber risk assessment and mitigation recommendation. In *Proceedings of the 50th Hawaii International Conference on System Sciences* (pp. 5968-5977).

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80	Lück, D., & Leyh, C. (2017). Enabling business domain-specific e-collaboration: Developing artifacts to integrate e-collaboration into product costing. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 296-312). Cham, Switzerland: Springer.
81	Malgonde, O., & Hevner, A. (2017). Finding evidence for effectual application development on digital platforms. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 330-347). Cham, Switzerland: Springer.
82	Matzner, M., Chasin, F., Hoffen, M. v, Plenter, F., & Becker, J. (2016). Designing a peer-to-peer sharing service as fuel for the development of the electric vehicle charging infrastructure. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 1587-1595).
83	Melville, N. P., & Zik, O. (2016). Energy points: A new approach to optimizing strategic resources by leveraging big data. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 1030-1039).
84	Moellers, T., Bansemir, B., Pretzl, M., & Gassmann, O. (2017). Design and evaluation of a system dynamics based business model evaluation method. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 125-144). Cham, Switzerland: Springer.
85	Morana, S., Schacht, S., & Maedche, A. (2016). Exploring the design, use, and outcomes of process guidance systems—a qualitative field study. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 9661, pp. 81-96). Cham, Switzerland: Springer.
86	Morschheuser, B., Hamari, J., Werder, K., & Abe, J. (2017). How to gamify? A method for designing gamification. In *Proceedings of the 50th Hawaii International Conference on System Sciences* (pp. 1298-1307).
87	Mramba, N., Tulilahti, J., & Apiola, M. (2016). Bookkeeping for informal workers: Co-creating with street traders. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 9661, pp. 97-113). Cham, Switzerland: Springer.
88	Müller, H., Bosse, S., Wirth, M., & Turowski, K. (2017). Collaborative software performance engineering for enterprise applications. In *Proceedings of the 50th Hawaii International Conference on System Sciences* (pp. 391-400).
89	Nguyen, H. D., Poo, D. C. C., Zhang, H., & Wang, W. (2017). Analysis and design of an mhealth intervention for community-based health education: An empirical evidence of coronary heart disease prevention program among working adults. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 57-72). Cham, Switzerland: Springer.
90	Notheisen, B., Gödde, M., & Weinhardt, C. (2017). Trading stocks on blocks—engineering decentralized markets. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 474-478). Cham, Switzerland: Springer.
91	O'Leary, C., Mtenzi, F., & McAvinia, C. (2016). Understanding the everyday designer in organisations. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 9661, pp. 114-130). Cham, Switzerland: Springer.
92	Papadopoulos, H., & Korakis, A. (2016). Adherence to medical recommendations and treatments by elderly patients: Useful Web services addressing this challenge. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 3438-3444).
93	Przeybilovicz, E., Cunha, M. A., & Póvoa, A. (2017). Budget transparency for monitoring public policies: Limits of technology and context. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 282-295). Cham, Switzerland: Springer.
94	Raber, D., Epple, J., Winter, R., & Rothenberger, M. (2016). Closing the loop: Evaluating a measurement instrument for maturity model design. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 4444-4453).
95	Reuter-Oppermann, M., Morana, S., & Hottum, P. (2017). Towards designing an assistant for semi-automatic EMS dispatching. In *Proceedings of the 50th Hawaii International Conference on System Sciences* (pp. 3556-3565).
96	Schilling, R. D., Aier, S., Brosius, M., Haki, M. K., & Winter, R. (2017). Extending CCM4DSR for collaborative diagnosis of socio-technical problems. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 247-263). Cham, Switzerland: Springer.

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97	Sjöström, J. (2017). DeProX: A design process exploration tool. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 447-451). Cham, Switzerland: Springer.
98	Strohmann, T., Siemon, D., & Robra-Bissantz, S. (2017). Brainstorm: Intelligent assistance in group idea generation. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 457-461). Cham, Switzerland: Springer.
99	Tagle, B., & Bernhardsson, H. (2016). Conclusion to an intelligent agent as an economic insider threat solution: AIMIE. In *Tackling Society's Grand Challenges with Design Science* (LNCS vol. 9661, pp. 147-157). Cham, Switzerland: Springer.
100	Tofangchi, S., Hanelt, A., & Kolbe, L. M. (2017). Towards distributed cognitive expert systems. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 10243, pp. 145-159). Cham, Switzerland: Springer.
101	Venkatraman, S., Sundarraj, R. P., & Mukherjee, A. (2016). Prototype design of a healthcare-analytics pre-adoption readiness assessment (HAPRA) instrument. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 9661, pp. 158-174). Cham, Switzerland: Springer.
102	Wagenknecht, T., Levina, O., & Weinhardt, C. (2017). Designing anonymous collaboration in computer-supported organizational participation. In *Proceedings of the International Conference on Design Science Research in Information System and Technology* (LNCS vol. 9661, pp. 90-103). Springer, Cham.
103	Werner, M. (2016). Process model representation layers for financial audits. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 5338-5347).
104	Wilson, D. W., Jenkins, J., Twyman, N., Jensen, M., Valacich, J., Dunbar, N., Wilson, S., Miller, C., Adame, B., Lee, Y. H., Burgoon, J., & Nunamaker, J. F. (2016). Serious games: An evaluation framework and case study. In *Proceedings of the 49th Hawaii International Conference on System Sciences* (pp. 638-647).

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