PRINCIPLES FOR KNOWLEDGE CREATION IN COLLABORATIVE DESIGN SCIENCE RESEARCH

Completed Research Paper

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Abstract

Design Science Research (DSR) advances the scientific knowledge base while at the same time leading to research results of practical utility. Several guidelines for DSR have been proposed to support researchers in their work. Collaborative forms of DSR require that knowledge be created across the boundaries of the research community and the practitioners' community. Only little research, though, has been undertaken so far investigating the topic of knowledge creation in collaborative DSR settings. Answers to fundamental questions are still missing: What knowledge creation processes are used? What problems may occur during researcher-practitioner collaboration? This paper addresses the gap in literature by taking a knowledge creation perspective on DSR. Based on a literature review and findings from the field it proposes a set of principles for knowledge creation in collaborative DSR.

Keywords: Collaboration, Design Science, Information system research, Knowledge creation, Research methods/methodology

Introduction

Motivation and Problem Statement

The relevance of research results has been a subject of discussion in the Information Systems (IS) community for quite some time now. In the 1990s, Benbasat et al. (1999), for example, made suggestions for increasing the relevance of IS research. Galliers (1994) discussed the balance between scientific rigor and practical relevance of research results. At the same time, the community made first steps in transferring design-oriented research principles from engineering disciplines to IS (cf. March and Smith 1995; Simon 1998; Walls et al. 1992). These efforts were driven—not exclusively, but in part—by the motivation to overcome the "relevance gap" because artifacts, as the result of design science, are by definition purposeful and aim at providing "value or utility" (March and Smith 1995, p. 253). This early work formed the foundation for further promotion of the idea of design-orientation in IS toward guidelines and principles for Design Science Research (DSR). Prominent examples of this have been the guidelines proposed by Hevner et al. (2004), the recommendations by Rossi and Sein (2003), and the Design Science Research Methodology (DSRM) by Peffers et al. (2008). With DSR being an accepted and important research approach in IS, researchers today are focusing on elaboration and further development of existing DSR guidelines. Rosemann and Vessey (2008), for example, propose applicability checks, and Frank (2007) provides a framework for evaluating reference models.

Design artifacts aim at contributing to the scientific body of knowledge. At the same time, they are supposed to solve practical problems. Considering this "duality", it is apparent that particularly collaborative DSR projects require both researchers and practitioners to be involved. Practitioners often participate in collaborative DSR projects to help researchers find out what has to be designed in the first place from a practical standpoint. Consequently, IS research since recently has been investigating on the collaboration of researchers and practitioners in collaborative DSR projects. One example has been the analysis by Mathiassen and Nielsen (2008) on the adoption of the engaged scholarship approach in IS research. Another example refers to Van de Ven (2007, pp. 27-28), who has identified "design and evaluation research" as one of four alternative forms of the engaged scholarship approach.

All major DSR guidelines stipulate the need to combine knowledge and expertise from both domains, the practitioners' and the scientific community. For example, Hevner et al.'s (2004) incorporation of "business needs" into the research as well as DSRM's "Problem Identification & Motivation" phase (Peffers et al. 2008) require both practical and scientific knowledge.

The IS community, however, has remained silent when it comes to providing methodological guidance for knowledge creation in the course of researcher-practitioner collaboration in DSR. Almost no recommendation is available supporting researchers in finding answers to the question as to how knowledge can actually be created in a collaborative setting.

Research Question and Paper Structure

In an effort to shed light on this still quite unexplored topic, the paper is addressing the following research question: What principles should guide knowledge creation involving researchers and practitioners in collaborative DSR settings? This research question can be operationalized by three further questions: (i) What approaches—relating to both comprehensive research methods, such as case study research, and measures taken by practitioners, such as requirements specification, for example—are currently being used for knowledge creation in collaborative DSR? (ii) What problems and obstacles do researchers and practitioners encounter? (iii) What principles should be followed to overcome the obstacles in knowledge creation in collaborative DSR?

To approach these questions, the paper develops a conceptual framework based on existing theory on knowledge management and organizational knowledge creation. The framework then guides the analysis of the current state with regard to knowledge creation in collaborative DSR settings, which is carried out in the form of a detailed literature review. Results from the literature review are then validated against findings from the field (gained from expert interviews with European IS professors and from an online

survey among design science researchers). Finally, a set of principles for knowledge creation in collaborative DSR is proposed, before the paper concludes with a summary of the results and an outlook to future research.

Theoretical Background

Knowledge Creation Theory

Fundamental concepts regarding the question as to how knowledge is created in organizations were investigated by Nonaka and Takeuchi (Nonaka 1994; 1995), stating that organizational knowledge is created through ongoing conversion and transfer of tacit and explicit knowledge. Tacit knowledge is personal knowledge which people are aware of, but which they cannot make available to others (Polanyi 1958). Therefore, exchange of tacit knowledge requires a high level of trust and intensive interaction between people. In contrast to tacit knowledge, explicit knowledge is articulated and documented in the form of certain (scientific) standards. Based on these foundations, Nonaka and Takeuchi (1995) introduced the SECI model, which describes four knowledge creation processes in organizations. *Socialization* is the transfer and exchange of tacit knowledge through interaction of individuals, e.g. by means of observation and imitation. *Externalization* is the conversion of tacit knowledge into explicit knowledge. *Combination* is the creation of knowledge through the merging of pieces of explicitly available knowledge, e.g. by means of conversation or the use of information systems. *Internalization* is the conversion of explicit knowledge into tacit knowledge.

These four knowledge creation processes are performed sequentially and in cycles. Thus, internalization of the first cycle forms the starting point for socialization in the second cycle. This cyclic nature of knowledge creation is often referred to by the metaphor of a spiral. Later on, the SECI model was revised mainly through the introduction of the concept of a shared context in which knowledge creation takes place (Nonaka and Konno 1998; Nonaka and Toyama 2003). This shared context—called *Ba*—comprises ethical, emotional, physical, and virtual concepts.

Despite being criticized for its lack of empirical value (Gourlay 2003) and its sole focus on knowledge creation processes (Grant 1996), the SECI model has been widely used in the IS community (e.g. Lee and Choi 2003; Orlikowski 2002).

DSR and Knowledge Creation

DSR wants to achieve a twofold goal: advance the scientific body of knowledge and provide results of practical utility. In doing so, DSR addresses a fundamental discussion about the nature of knowledge and its meaning for scientific research. Numerous contributions have pointed out the difference between "knowledge that" (i.e. scientific knowledge leading to truth) and "knowledge how" (i.e. applied knowledge and technologies) (Gibbons et al. 1994; Niedderer 2007). Similarly, one has to be aware of the ambiguous conceptualization of the term "design". Design can be interpreted both as the process of designing (i.e. a design activity) and as the result of a design activity (i.e. a design artifact itself). While according to the first interpretation the artifact is considered the "carrier" of scientific knowledge, the second interpretation considers the design process itself as a design artifact (a method, for example). Interpreting the design process as an artifact refers mainly to "technological rules" (Bunge 1966; van Aken 2004). Carlsson (2006) has defined a technological rule as "a chunk of general knowledge, linking an intervention or artifact with a desired outcome or performance in a certain field of application".

The question, though, as to how researchers and practitioners should create knowledge in collaborative DSR projects is still relatively unexplored. Otto and Österle (2011) address the issue by analyzing three cases from literature. The majority of research in this area, though, mainly reports on individual cases of researcher-practitioner collaboration. Lindgren et al. (2004), for example, report on the development of design principles for competence management systems. An Mathiassen (2002) propose collaborative practice research based on a case study analysis. Apart from that, some researchers have proposed integrative approaches combining DSR with action research. Examples have been the DAGS Framework proposed by Adams and Courtney (2004), and the work by Järvinen (2007) on the similarities between

DSR and action research. These contributions implicitly deal with researcher-practitioner collaboration due to the participative nature of action research as a research method.

However, major DSR recommendations, as of today, do not address the question of knowledge transfer in a manner useful for researchers conducting a DSR project. Hevner et al. (2004), for example, stipulate that design artifacts be rigorously evaluated and that "evaluation includes the integration of the artifact within the technical infrastructure of the business environment" (p. 85). However, they do not elaborate in more detail how this should be achieved. And Peffers et al. (2008) demand for the DSRM phase "Definition of the objectives of the solution" that "resources required for this include knowledge of the state of problems and current solutions, if any, and their efficacy" (p. 55), but do not specify this any further.

The need for research in this area has been articulated by a number of researchers. Hjalmarsson et al. (2010) argue that designers often were not in control in collaborative DSR settings. And Wieringa (2010) points out that in DSR projects the problem solving expertise in the practitioners' community should be treated as equally as important as the researchers' knowledge.

Research Approach

Research Process

The process of the research presented in this paper consists of four steps. The first step develops a conceptual framework that guides the further course of the study. The conceptual framework (see below) draws upon the theoretical background with regard to organizational knowledge creation on the one hand and research on DSR guidelines on the other. The second step comprises a detailed literature review aiming at identifying approaches for knowledge creation in collaborative DSR. The literature review follows the principles proposed by Webster and Watson (2002). The third step validates the results from the literature review against findings from the field (an online survey among design science researchers and expert interviews with eleven European IS professors). The fourth step derives principles for knowledge creation in collaborative DSR. The work in steps 1 to 3 was conducted in iterations to a large extent. The literature analysis began in 2009, and the last update was undertaken in 2012 (see Table 1). The expert interviews were conducted in Q2 and Q3 in 2009, while the online survey was carried out in between January and March 2011.

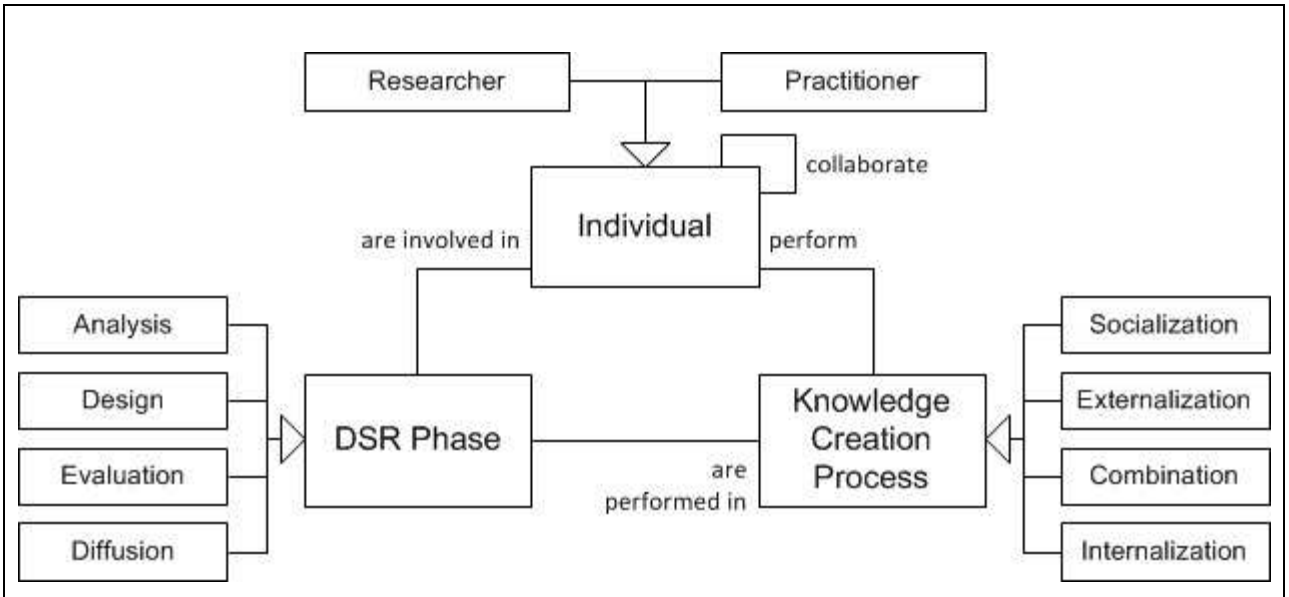

Figure 1. Conceptual Framework for Knowledge Creation in Collaborative DSR

Conceptual Framework

Figure 1 shows the conceptual framework used to guide the further course of the study. The central concepts of the framework are "Individual", "DSR Phase", and "Knowledge Creation Process". "Individuals" involved in a collaborative DSR project are either researchers or practitioners. The framework does not take into account groups and organizations as proposed by Nonaka and Toyama (2003), as the focus is on knowledge creation processes between individuals. Furthermore, the conceptual framework draws upon recent contributions regarding the procedural nature of DSR, as it assumes four general phases in a collaborative DSR project, namely "Analysis", "Design", "Evaluation", and "Diffusion" (Österle and Otto 2010). Finally, the framework comprises the four knowledge creation processes of the SECI model (see above). The framework assumes that individuals collaborate with each other in a DSR phase by performing a knowledge creation process.

Literature Search

Five scientific databases, namely AIS Electronic Library, ACM Digital Library, CiteSeerX, EBSCO Online, and Emerald (see Table 1), were queried for papers that contain certain keywords. The queries used three different composite search terms in order to cover all elements of the conceptual framework. The three search terms used were [("Design Science" OR "Design Research") AND "Knowledge"], [("Design Science" OR "Design Research") AND ("Collaboration" OR "collaborative")], and [("Design Science" OR "Design Research") AND ("Practitioner" OR "Practice")]. The results were then filtered in order to identify papers addressing at least three elements of the conceptual framework in their abstracts. The list of papers dropped was screened to ensure that promising papers were not excluded only because of an "incomplete" abstract. This step led to three papers being included in the final list despite being disregarded first. One of them is the paper by vom Brocke et al. (2008), who report on the transformation of DSR into practical application in the field of Enterprise Content Management.

Table 1. Search in Scientific Databases

Database	AIS Electronic Library	ACM Digital Library	CiteSeerX	EBSCO Online	Emerald
Most recent search date	05/02/12	05/02/12	05/02/12	05/12/12	04/12/11
Search functionality	Advanced Search	Advanced Search	Advanced Search	Find Articles by Text, use Guided Criteria	Advanced Search in Journals
Search fields	Abstract	Abstract	Abstract	Title, Abstract	All except full text
Search filters	Peer-reviewed only	Limit search to journals, proceedings, transactions	Disregarded were papers which use "practice" in the sense of "approach"	Limit search "Social Science", "Technology"	Conceptual papers and reviews were disregarded

In a next step, forward and backward analysis (cf. Webster and Watson 2002) was carried out in order to make sure no cited or citing papers had been overlooked. Finally, 33 papers made it to the literature review (see Table 2). These papers can be grouped into three categories. The first group of papers describes cases of collaborative DSR in which knowledge creation is addressed. An example is the above mentioned report by vom Brocke et al. (2008). The second group of papers deals with the theoretical foundations of knowledge creation in collaborative forms of DSR. Carlsson (2006), for example, takes a critical realist perspective when developing an IS design research framework, touching upon the collaboration of practitioners and researchers and the question of knowledge creation. The third group includes guidelines, methodologies, or tools to support knowledge creation in collaborative DSR. Plsek et

al. (Plsek et al. 2007), for example, elaborate on how to extract design rules from the experience of organizational managers.

With the 33 papers resulting from the literature search, a qualitative data analysis (Cavana 2001; Creswell 1998) was carried out to identify the current state of literature with regard to knowledge creation in collaborative DSR. The analysis used axial coding techniques for data interpretation. The concepts from the conceptual framework worked as codes. The software tool "Weft QDA" was used to support the qualitative data analysis. Weft QDA is free software, which was chosen mainly because it allows importing PDF files. A first coding process was applied on a composite concept level, i.e. paragraphs and words were coded with "Design Science Research", "Knowledge Creation" etc. A second, more detailed coding process was then applied on the level of the individual concepts. In a final step, an open-coding strategy was applied to identify current obstacles in knowledge creation in collaborative DSR settings.

Table 2. Literature Search Results

Type of contribution	Papers
Case descriptions	(Adikari et al. 2006), (Adisa et al. 2010), (Bielaczyc 2006), (Biloria 2007), (Karacapilidis et al. 2005), (Mathiassen 2002), (Moon and Ngai 2010), (Nfuka and Rusu 2011), (Pascal et al. 2009), (vom Brocke et al. 2008)
Papers on theoretical foundations	(Carlsson 2006), (Gregor and Jones 2007), (Henningson et al. 2010), (Hevner et al. 2004), (Iivari and Venable 2009), (Järvinen 2007), (Offermann et al. 2011), (Ondrus and Pigneur 2009), (Otto and Österle 2011)
Papers dealing with guidelines, methodologies, or tools	(Anggreeni and van der Voort 2008), (Avital et al. 2006), (Bielaczyc 2006), (Clark 2008), (Denyer et al. 2008), (Holmström et al. 2009), (Jonas 2007), (Mathiassen 2002), (Ondrus and Pigneur 2009), (Österle and Otto 2010), (Pilerot and Limberg 2010), (Plsek et al. 2007), (Wastell et al. 2009), (Zimmerman et al. 2010)

Expert Interviews and Online Survey

The paper uses a twofold validation approach to triangulate the findings from the literature review. First, findings from expert interviews with eleven tenured IS professors and chair holders at European universities were used. The expert interview study mainly aimed at providing insight with regard to the need to balance between scientific rigor and practical relevance in European DSR. It was conducted via a semi-structured interview guideline using ten open questions. One of the three topics addressed was the collaborative creation of knowledge by researchers and practitioners. The preliminary results—without comprehensive grounding in literature and without propositions for future research—were presented to the IS community (Otto and Österle 2010).

Second, the paper uses the results of an online survey among design science researchers for validation purposes. The call for participation in the survey was sent to the members of the Association for Information Systems (AIS). The survey aimed at providing insight into the collaboration between researchers and practitioners in DSR in general and with regard to collaborative creation of knowledge in particular. Three questions out of six dealt with the knowledge creation aspect, namely the question concerning research methods used for knowledge creation in collaborative DSR, the question on knowledge creation processes used (according to the SECI model), and the question concerning challenges and problems that are encountered. The questions were closed and allowed multiple responses. 34 researchers took part in the survey between January and March 2011. The questionnaire and the plain survey results are available as working report (Otto and Österle 2012).

Current State Regarding Knowledge Creation in Collaborative DSR

Knowledge Creation Approaches

Table 3 summarizes the approaches used for collaborative knowledge creation during the different DSR phases as described in literature.

Table 3. Approaches for Knowledge Creation in Collaborative DSR

DSR Phase	Knowledge Creation Process			
	Socialization	Externalization	Combination	Internalization
Analysis	AR, Face-to-Face Interaction, Living Requirements Space, Participatory Design, Scenario Building, Storytelling	AR, Appreciative Inquiry, CSR, Expert Interviews, Feasibility Studies, FG, Metrics, Reviewing Practitioners Publications, Reverse Engineering, Scenario Building, Storytelling, Surveys, User Site Visits	AR, Brainstorming, Creativity Techniques	AR, FG, Simulation
Design	AR, Participatory Design, Positive Lens Design, Prototyping, Scenario Building	AR, Feasibility Studies, Functional Tests, FG, Scenario Building	AR, Brainstorming, Creativity Techniques, Participatory Design, Prototyping	AR, FG, Simulation
Evaluation	AR, Experimentation, Face-to-Face Interaction, Participatory Design	AR, CSR, Expert Interviews, Feasibility Studies, Functional Tests, FG, Surveys	AR, Artifact Implementation, Brainstorming, Participatory Design, Prototyping	AR, FG, Informed Argument, Prototyping Simulation
Dissemination	AR, Experimentation, Scenario Building	AR, Scenario Building	AR, Artifact Implementation, Brainstorming, Prototyping	AR, Prototyping

Legend: AR - Action Research; CSR - Case Study Research; FG - Focus Groups.

Socialization, being the knowledge creation process in which tacit knowledge is exchanged, is addressed by a number of papers. Many authors stress the importance of action research in collaborative DSR (Carlsson 2006; Holmström et al. 2009; Mathiassen 2002), as action research is by definition a form of research which is based on the collaboration and interaction of individuals. Järvinen (2007, p. 50) also points out that although "in action research the knowledge produced was not explicated much, it concerns both the process and its result". Furthermore, participatory design is seen as a promising approach to foster socialization of knowledge in collaborative DSR. It is assumed that learning-by-doing techniques and practices in participatory design "were born out of the belief that the 'natives', 'locals', or 'skilled practitioners' are best suited for defining and refining their practices through action in design activities" (Clark 2008, p. 206). The interactive nature of socialization activities is also taken up by Avital et al. (2006), who propose a "Positive Lens Design" approach, aiming—among other things—to examine and

enhance positive modalities in human dynamics. In contrast to these comprehensive methodological contributions, other papers propose concrete measures to foster socialization. Pilerot and Limberg (2010), for example, elaborate on face-to-face interactions and Pascal (2009) describes experimentation as the collaborative testing of artifacts between researchers and practitioners.

Externalization (i.e. conversion of tacit knowledge into explicit knowledge) is the knowledge creation process most frequently addressed in literature. A variety of approaches exists, including both "mainstream" research methods and more project management oriented activities. Among the commonly accepted methods are action research, case study research (Moon and Ngai 2010), expert interviews (Pascal et al. 2009), focus groups (Anggreeni and van der Voort 2008), surveys, and testing. In order to specify the objectives of a desired solution, for example, many researchers conduct interviews with practitioners (Moon and Ngai 2010; Pascal et al. 2009). Adisa et al. (2010) have coined the notion of a "pain point analysis", but do not explicate this any further. To triangulate the results of interviews, researchers propose a variety of methods. One example is the analysis of practitioners' publications, such as articles in trade magazines or annual company reports (Moon and Ngai 2010). For evaluating design artifacts, many researchers propose tests (Hevner et al. 2004; Jones and Gregor 2006), both under "real-life" and laboratory conditions. A method not frequently used is appreciative inquiry (Avital et al. 2006), aiming at involving all organizational levels and stakeholders in the search for "best practices" (Cooperrider and Whitney 2005). Apart from that, Moon and Ngai (2010) propose feasibility analysis as a means to externalize practitioners' knowledge. A third example of niche methods includes visiting user sites in the Analysis phase of a DSR project in order to be able to "better understand the daily industrial practices involved [...] in an actual setting" (Moon and Ngai 2010). Another unusual practice is "storytelling", as proposed by Plsek et al. (2007), who see this method as an appropriate means to identify technological rules in the interaction with practitioners without needing to follow a too formalized method. Finally, a number of researchers propose concrete measures to support externalization of knowledge in collaborative DSR. One example is to specify the objectives of a new solution through metrics (Järvinen 2007; Mathiassen 2002), as metrics translate the utility of a design artifact into a language business understands.

The most prevailing approaches for **combination** of explicit knowledge are action research and participatory design. Both relate, by definition, to interactive and joint execution of research and design activities. Recently, Sein et al. (2011) have proposed Action Design Research (ADR) as an approach to address the shortcomings of existing DSR methods regarding contextual and organizational integration of the design artifact. Furthermore, prototyping of design artifacts is seen as a promising approach to combine explicit knowledge (Henningson et al. 2010; Hevner et al. 2004; Jones and Gregor 2006). Holmström et al. (2009) refer to prototypes as "rudiments" of the final design, pointing out that also technological rules represent prototypes, namely prototypes of design process knowledge. Apart from that, creativity techniques, such as brainstorming or morphological analysis, are considered appropriate means to facilitate collaborative creation of knowledge in DSR projects.

Various approaches are used when it comes to **internalization** of knowledge (i.e. conversion of explicit knowledge into tacit knowledge). The list of methods applied includes action research (Carlsson 2006; Clark 2008), focus groups (Henningson et al. 2010), and simulation techniques (Adikari et al. 2006; Biloria 2007; Hevner et al. 2004). In addition to that, Hevner et al. (2004) propose the informed argument technique to demonstrate the utility of a design artifact.

Obstacles Incurred

Despite the variety of knowledge creation approaches proposed and used by IS researchers, the current state with regard to knowledge creation involving researchers and practitioners in collaborative DSR settings is characterized by a number of obstacles (see Table 4).

Obstacle 1—lack of appropriate skills—relates to both the community of researchers and the community of practitioners. With regard to the former, Clark (2008), for example, points out that often researchers are unable to appropriately articulate the nature and advantages of collaborative forms of DSR, leading to lost research opportunities. And Holmström et al. (2009) argue that often researchers are lacking skills and background required to make themselves familiar with the challenges and problems of a senior executive with decades of professional experience. However, a lack of appropriate skills can be identified for the

practitioners' community, too. Vom Brocke et al. (2008), for example, have experienced practitioners "usually unskilled in executing adequate evaluation (justification) methods". This point is confirmed by the aforementioned to use rather informal techniques, such as storytelling, to make practitioners' knowledge available for scientific purposes.

Table 4. Obstacles Incurred

Obstacle	Description	Evidence in literature
1	Lack of appropriate skills	(Clark 2008), (Holmström et al. 2009), (vom Brocke et al. 2008)
2	Diverging stakeholder interests	(Avital et al. 2006), (Henningson et al. 2010), (Mathiassen 2002)
3	Inappropriate methods	(Anggreeni and van der Voort 2008), (Avital et al. 2006), (Mohrman 2007)
4	Access to the "right" resources	(Henningson et al. 2010)
5	Disconnection of artifact design and artifact implementation	(Avital et al. 2006), (Pascal et al. 2009), (Wastell et al. 2009)
6	Insufficient research capacities	(Mathiassen 2002)

Obstacle 2—diverging stakeholder interests—relates to the often cited difference in expectations of the research community and the practitioners' community. Typically, researchers are interested in "truth", while practitioners want solutions that work. This frequently leads to situations in which practitioners push for results at the expense of scientific rigor (Mathiassen 2002). Moreover, researchers are interested in publishing research results which might include "sensitive proprietary information that cannot be shared with other organizations" (Margaryan 2008). Other problems of this category are conflicts of interest on the side of the practitioners (e.g. power imbalances) (Avital et al. 2006) or the lack of practitioners' commitment (Henningson et al. 2010).

Obstacle 3—inappropriate methods—refers to the lack of appropriate methods supporting both researchers and practitioners in the course of the collaboration. Some researchers argue that most methods assume an "ideal world" and do not take into account actual skills and capabilities of individuals (Avital et al. 2006). Other researchers point to a more general shortcoming of existing methods to externalize tacit knowledge of the practitioners' domain. Anggreeni and van der Voort (2008), for example, refer to incomplete documentation of existing instantiations, wondering how to specify the objectives of a new solution when knowledge about the current state of practice is poor (since incomplete). And Mohrman (2007) asks how much knowledge can actually be formalized.

Obstacle 4—access to the "right" resources—refers to a general problem in collaborative DSR projects, namely personal discontinuity of key resources critical for the project's success. Henningson et al. (2010), for example, point out that often certain key individuals possess knowledge and skills that are not replaceable.

Obstacle 5—disconnection of artifact design and artifact implementation—is articulated by Avital et al. (2006), for example, who speak of "isolated activities" taking place in either of these two phases. And Pascal et al. (2009) stress that "producing artifacts is not sufficient: in a multi-actor environment, the dialogue and negotiations with users have to be deliberately created and managed". One reason for this shortcoming might be found in the diverging stakeholder interests (see Obstacle 2). Or, as Wastell et al. (2009) put it: "[Problematic is t]he tendency in design work to incorporate novel features that please the intellectual curiosity of the designer, rather than the pragmatic needs of users".

Finally, Obstacle 6—insufficient research capacities—relates to the contribution of the researchers in a collaborative setting. Mathiassen (2002), for example, finds that collaborative practice research (as a form of researcher-practitioner collaboration) requires "large efforts".

Validation of Findings

Knowledge Creation Approaches

The findings in literature with regard to approaches used to facilitate knowledge creation in collaborative DSR are supported by the results of the online survey to a certain extent. 21 out of 25 respondents confirmed the use of case studies. However, surprisingly enough, empirical methods such as expert interviews (15 out of 25), surveys (14 out of 25), and focus groups (twelve out of 25) follow next. This result does not correspond with literature, which indicates a more intensive use of approaches which are collaborative by nature—such as participatory design, for example. Furthermore, literature suggests that action research is by far the most powerful approach for knowledge creation across all DSR phases and knowledge creation processes. In contrast to that statement, only eleven out of 25 respondents in the online survey claimed to have used this method. The same is true when it comes to prototyping (ten out of 25). Apparently, a certain contradiction can be identified in the IS community between what should be done and what is actually being done. One explanation for this misfit was addressed in the expert interviews. Three experts pointed out that a certain level of intensity in the collaboration between researchers and practitioners was needed. Supervision of joint master theses or infrequent information exchange workshops could not be considered sufficient. Practitioners needed to make a clear commitment—regarding time, knowledge, and money, for example—to the collaboration in order to make it productive. As far as the balanced picture the literature review shows with regard to the four different knowledge creation processes is concerned, the online survey is largely confirmative. The respondents said to have experience with socialization (14 out of 26), externalization (17 out of 26), combination (15 out of 26), and internalization of knowledge (13 out of 26).

Obstacles Incurred

The findings on obstacles incurred for knowledge creation in collaborative DSR projects that were identified in literature are partially supported by own data gained in the field.

With regard to Obstacle 1—lack of appropriate skills— six out of 27 respondents in the online survey stated that insufficient project management capabilities on the researchers' side hindered the creation of knowledge. Support for this can be found in the expert interviews, with one expert saying that IS research first had to achieve a certain status (of expertise) before access to knowledge carriers was granted by partner companies. It was further stated that in order for researchers to be taken seriously by practitioners it was necessary for the former to stick to a certain topic for a considerable amount of time, as otherwise research would not be able to build up the knowledge required to discuss with business at eye level. The unwillingness to grant insight into failed projects also falls within this category, which is why Mertens (2008) calls for more research on IS project failures.

Obstacle 2—diverging stakeholder interests—was considered by far the biggest challenge to knowledge creation in collaborative DSR settings. Two thirds of the respondents in the online survey reported to have personally encountered this challenge. One participant in the expert interviews elaborated on this point when explaining that researchers were often interested in publishing project results which practitioners wanted to keep confidential. According to this expert, the more innovative the outcome of a project is, the more unlikely it is that the results are published.

As far as Obstacle 3—inappropriate methods—is concerned, one the one hand a demand for a "cross-community" context was articulated in the expert interviews, as researchers had limited time due to other goals they have or want to achieve (academic career, teaching, academic self-administration etc.), while practitioners would ask for fast results, often at the expense of scientific rigor. Furthermore, one participant in the online survey said that "conceptualization of what is being researched is probably the most important thing". Referring to the lack of methods he calls for—what he calls—"ontology management". This idea was also supported in the expert interviews, as one expert said that different terminology and language in general hindered efficient collaboration between researchers and practitioners. He argued that as a researcher "if one does not speak the language of practitioners, he or she will not be able to understand the answers" to his/her questions.

Obstacle 4—access to the "right" resources—was addressed both in the online survey and in the expert interviews. One expert said that collaboration with practitioners was not valuable per se, but that the researcher "has to catch the right persons", i.e. those who are truly knowledgeable. This relates to the question regarding "best design knowledge", which is often demanded by partner companies collaborating with academic researchers. Some interviewees pointed out that it was often not easy to distinguish between "best practice" and "just good or moderate practice". Personal discontinuity as a resource problem was confirmed by six out of 27 respondents in the online survey. However, in the list of eight challenges asked for, this item ranks fifth. Thus, it was not deemed to be of strong impact.

Obstacle 5—disconnection of artifact design and artifact implementation—was mainly supported in the expert interviews. As one participant slightly provocatively pointed out: "Sometimes we conduct workshops with practitioners to evaluate designs. We invite them to us, put them in a workshop room, and 'bribe' them with a nice atmosphere and good food, hoping that would make them come to a favorable evaluation decision."

Obstacle 6—insufficient research capacities—was largely confirmed in the expert interviews. One expert said that manpower was clearly bigger in the practitioners' community, and that due to such limitations IS research could only pick up individual questions.

Principles for Knowledge Creation in Collaborative DSR

Based on the literature review and the validation of the findings against own data collected in the field, the paper proposes a set of principles to guide knowledge creation in collaborative DSR (see Table 4).

Table 4. Principles for Knowledge Creation in Collaborative DSR

Principle	Description	Concrete measures to be taken
1	Formalize shared goals	Researchers and practitioners put up a common project agreement Researchers and practitioners commonly define requirements for the solution to be developed and the artifact to be evaluated
2	Collaborate through action	Researchers and practitioners develop common design principles Researchers and practitioners perform joint design activities
3	Conduct full learning cycle	Practitioners test artifacts in real-life environments at practitioners' sites Researchers triangulate findings at multiple sites
4	Allow for trial and error	Researchers and practitioners prepare for multiple design/test cycles and heuristic search activities
5	Make significant commitments	Practitioners contribute with their resources (time, expertise, funding) Researchers and practitioners collaborate over a significant amount of time
6	Involve complementary roles	Practitioners grant access to multiple carriers of knowledge in their organization Researchers provide both research and management skills

Principle 1—formalize shared goals—addresses the misfit in the understanding and communication between researchers and practitioners. If it is commonly accepted that artifact design is a search process, this holds true also for the very early phases of a collaborative DSR project, namely identification of the problem and specification of the objectives. Venable (2006) interprets a thorough understanding of the problem space as a "distinct form of research" and a "precursor" to DSR. This paper takes a slightly different viewpoint in this regard as it stipulates the "Analysis" phase of a collaborative DSR project as iterative as well and integral to DSR. How else should the researchers know what to design anyway without a thorough understanding of the problem space? And Henningson et al. (2010) summarize: "In retrospect, it had been useful to define the research aim in closer collaboration with practitioners."

Principle 2—collaborate through action—stresses the need that collaboration between researchers and practitioners must be characterized by a certain level of intensity. Also, Wastell et al. (2009, p. 345) come to the conclusion that "had we worked more collaboratively and iteratively with our users (using prototypes, for instance, to explore design ideas), we may well have produced not only a better artefact [sic!] […] but more robust theory too". The complementary role action research as a participatory form of research can play in collaborative DSR projects has been discussed by many researchers (Hjalmarsson et al. 2010; Iivari and Venable 2009; Järvinen 2007). Most notably in this regard is Action Design Research (Sein et al. 2011) as an integrated approach to action research in DSR. Moreover, case studies allow for in-depth insight to knowledge in the practitioners' community and its transformation to scientific knowledge. Focus groups can be used to explore potential design alternatives and confirm design decisions (Chiarini Tremblay et al. 2010). Creativity techniques in general support the co-creation of knowledge. A vividly discussed example is Design Thinking as an approach to combine empathy and creativity in the progress of finding novel solutions to relevant design problems (Lindberg et al. 2011; Lockwood 2010). Design Thinking aims at solutions to concrete design problems. The fundamental concepts, though, can also be applied in DSR cases. Apart from that, prototypes are well suited to support collaborative design because they function as a means to facilitate collaborative knowledge creation between researchers and practitioners (cf. Carlile 2004).

Principle 3—conduct full learning cycle and allow for trial and error—is key to knowledge creation across all four DSR phases. This principle includes two main aspects. First, knowledge creation in DSR projects not only requires design, but also implementation. Design artifacts cannot be evaluated without being deployed in a "real-life" environment. This is the reason why Moon and Ngai (2010) stipulate the creation of an implementation plan, for example. This point is supported by Jones and Gregor (2006) who argue that "testing […] instantiations […] within a real organizational setting reveals perceptions, issues and problems that are not readily visible when limited to a prototype or theoretical instantiation". Furthermore, due to their structural complexity some design artifacts can be studied properly only when implemented. An analogy for this phenomenon taken from production management is Intel's "Copy Exactly!" approach (McDonald 1997). Intel makes sure that manufacturing lines in research and development exactly match those in series production (even with regard to the diameter of piping, for example). Changes to the system are assessed by the effect on the system's performance under real-life conditions rather than by simulations or analyses "on paper". Second, design is an iterative search process for the best means-end relation of potential solutions to practical problem. Thus, researchers should not only conduct multiple generate/test cycles, but should also triangulate findings from one user site at other sites with multiple carriers of knowledge in order to increase the generalizability of the results.

Principle 4—allow for trial and error—recognizes artifact design as a search process which requires the continuous testing and refinement of a proposed solution, and often heuristic search activities (Hevner et al. 2004). This principle is of high importance as it forms the prerequisite for achieving double-loop learning effects, for example. Double-loop learning refers to the ability of an agent to redefine his/her problem-solving strategies after a perceived fault or error has occurred. In contrast, single-loop learning relates to simply improving the employment of the same techniques in situations similar to the one that led to the fault or error (Argyris and Schön 1978). In order to allow for double-loop learning through trial and error practitioners and researchers alike should balance their interest in timely results and rigor in artifact design.

Principle 5—make significant commitments—relates to the necessity that both researchers and practitioners must commit themselves to collaborative DSR. Practitioners need to make a clear commitment to the collaboration in order to make it productive. Examples of such a clear commitment could be to assign staff or release a budget to a joint project. In the expert interviews, project funding by practitioners was regarded as a clear indication of the depth of collaboration, because in each partner company someone "has to justify the euros to be spent". Researchers, on their part, need to ensure continuity over time and in terms of resources. "Spotty" measures, such as joint master theses or infrequent information exchange workshops, can only be one means to facilitate knowledge creation in collaborative DSR.

Principle 6—involve complementary roles—aims at leveraging maximum knowledge from the practitioners' community. Collaborating with one hierarchical level in a research partner company, for example, neglects the majority of requirements, concerns, and ideas relating to a newly designed artifact.

This is why Avital et al. (2006) propose appreciative inquiry, which is designed to use knowledge from various roles and hierarchical levels in an organization. Holmström et al. (2009) point out that evaluators of an artifact "are not the same scientists who developed the solution design". And Clark (2008) stipulates the role of a "facilitator" in bridging the differences between researchers and practitioners in a collaborative DSR project.

Conclusion and Outlook

Based on a literature review and a validation of the findings against own data collected in the field, the paper proposes a set of principles for knowledge creation in collaborative Design Science Research (DSR). The paper makes two contributions to the advancement of the scientific body of knowledge. First, it is among the first comprehensive studies on this emerging topic. DSR in general is seen as promising to help closing the often lamented gap between scientific rigor and practical relevance, and IS research and collaborative DSR in particular require a sound understanding of how knowledge can be efficiently created. Second, the principles for knowledge creation in collaborative DSR constitute a baseline for further research. Potential opportunities of future work lie in the further development of the principles toward a comprehensive method and in their empirical validation.

Limitations of the paper derive from its exploratory nature. As mentioned above, knowledge creation in collaborative DSR is an emerging topic which justifies the use of qualitative research approaches. Furthermore, the findings of the study refer to collaborative DSR only. The paper acknowledges the importance of DSR projects which are not based on intensive researcher-practitioner collaboration, and it does not claim its findings to be valid for the latter.

Practitioners may benefit from the results as well. The paper helps increase transparency of collaborative research settings. And, the results might also be taken up by research funding organizations demanding more efficacy in research, as the aforementioned Aho report does (EC 2008).

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