Towards an Open Repository for Design Science Research: A Meta-Model and its Instantiation for the Representation of Design Science Research Processes

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Abstract. *Design Science Research (DSR) is a well-established paradigm in the Information Systems field generating knowledge on the design of innovative solutions to real-world problems. The maturity of DSR has increased due to many methodological contributions, including conceptualization of the design process, templates on how to plan and document, as well as guidelines on how to conduct DSR projects. At the same time, given the dynamic nature of design in the digital era, DSR methods are also constantly further developed by the community. Both access to existing DSR methods and its further development are hindered today by the way we represent DSR methods. Most of the DSR methods are scattered in different papers or books. In order to foster accessibility and further development, we propose a harmonized representation of DSR process knowledge (as a core component of DSR methods) in an open repository. Applying DSR ourselves, we 1) identify meta-requirements for a DSR process modeling system 2) derive initial design principles 3) propose a meta-model 4) provide an instantiation of the meta-model in the form of an open repository, and 5) evaluate our design based on interviews with DSR researchers using the repository. We report from two DSR cycles, then discuss our findings and outline avenues for future research.*

Keywords. Research Methods • Process Modeling • Research Process Management • Design Science Research • Meta-Model

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1 Introduction

The Design Science Research (DSR) paradigm has its roots in the sciences and engineering of the artificial (Simon 1996). It is widely used in Information Systems (IS) to generate knowledge on the design of innovative solutions to real-world problems (Hevner et al. 2004). DSR researchers perform many tasks in exploring both the problem and solution space. They also design and evaluate artifacts, making use of many research methods along the way (Brocke et al. 2020). Various frameworks exist describing different approaches of design science research processes. Examples include the DSR frameworks provided by Hevner et al. (2004), Kuechler and Vaishnavi (2008), Peffers et al. (2007), Sein et al. (2011), the DSR communication schema proposed by Gregor and Hevner (2013), and guidance in the evaluation (Iivari et al. 2021; Sonnenberg and Brocke 2012; Venable et al. 2016). However, in specific research projects, DSR researchers need to creatively apply and adapt such frameworks to fit the specific constraints and opportunities of their research project at hand (Brocke et al. 2017).

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While phase models outline essential phases of a DSR project, design researchers have argued that any DSR project needs to be tailor-made towards its specific context and that the design of the research process is a key quality criterion for DSR projects (Brocke et al. 2021). Hence, over the course of the DSR process, selecting and applying research methods appropriately is crucial to achieving research rigor (Gregor and Hevner 2013), and many different research methods are available, such as case study research, experimental research, and survey-based research (Hevner et al. 2004). Scientific methods are a core component of any scientific discipline. By defining a standardized set of research activities, they enable researchers to build scientific knowledge. They explain how to make valid observations, interpret results, and generalize those results. Furthermore, scientific methods allow other researchers to test prior findings and theories independently of each other (Bhattacherjee 2012). Research methods are highly intertwined with research processes. Several definitions consider the process to be the core of the research method (Hugh 2003).

This diversity of research methods within research fields and in IS in particular, has been recognized as a positive source of strength (Robey 1996). However, it also leads to some challenges, for example, in selecting and applying research methods as well as in planning and communicating the overall DSR process (Brocke et al. 2017). Furthermore, research methods evolve and can have different levels of maturity, or even new branches emerge depending on the specific research approaches. This information is spread in different sources and lacks explicit documentation. In addition, most of the knowledge about research methods is described in unstructured text and lacks machine executability. Using non-formal languages to express and compare research methods has been shown to be problematic in the past. The limited expressive and formal power of narrative text means omitting ambiguity in applying and comparing described research methods becomes unavoidable (Leist and Rosemann 2011).

To increase accessibility and reusability, existing knowledge reuse frameworks suggest capturing, structuring, and distributing the existing knowledge (Markus et al. 2002). Additionally, prior research suggests applying a process-oriented view on research methods in general and on research process knowledge (Bonoma 1985; Leist and Rosemann 2011; Lovasz-Bukvova and Helena 2009; Miles et al. 2019). An approach to model research processes was presented by (Leist and Rosemann 2011). They suggested using the Business Process Model and Notation (BPMN) to describe research processes and demonstrated in various cases the power of process modeling to capture and visually depict research processes.

Currently, there exists no compressive repository for DSR methods to improve the accessibility of research methods beyond traditional formats and one-directional media, such as journals or textbooks. Furthermore, there is no dedicated tool support available for the comprehensive modeling and representation of DSR process knowledge that would enable accessibility, reuse, and evolution. In order to close this gap, we developed a repository facilitating the access and further development of research methods in the field of DSR. Additionally, we aim to deliver a first step towards a comprehensive overview of DSR methods available in the field of IS in order to deliver an entry point for less experienced design researchers, which could potentially be used (for example) by doctoral students and for more general educational purposes. Therefore, we propose to investigate the following research question (RQ):

RQ: *How to represent DSR process knowledge on an open repository for accessibility, reuse, and evolution?*

In this paper, we aim to contribute to the knowledge base of tool support in DSR with a particular focus on DSR process modeling as a key element for enabling DSR process knowledge representation. More specifically, we address the problems described above, and in two DSR cycles we deliver 1) meta-requirements for DSR process modeling 2) initial design principles based on the meta-requirements 3) a meta-model for research process conceptualization 4) instantiation of the meta-model embedded in a light-weight collaborative process modeling system on an open repository, and 5) report on the evaluation results. We implemented a publicly accessible prototype of a DSR process modeling system and populated an initial process knowledge base. We evaluated the prototype containing a set of process descriptions by interviewing modeling experts and DSR researchers in the Information Systems field. The prototype makes it possible to document and describe research methods and make their underlying processes explicitly available. On this basis, we enable other scholars to get an overview of the different approaches of research methods used in DSR, which serves as an entry point for researchers to get familiar with design science research methods. Furthermore, by creating an explicit representation of DSR process knowledge, we provide a foundation for reuse and evolution.

2 Conceptual Foundations

2.1 Scientific Methods

In the 19th century, the term "scientific method" emerged when a significant institutional development of science was taking place (Chalmers 1999). The process of delineating science from non-science, such as through the concepts of "scientist" and "pseudoscience", established these terminologies (Harrison et al. 2011). The scientific method describes the process by which science is carried out and aims to acquire scientific knowledge (Hugh 2003). However, there does not exist a single recipe on how to apply the scientific method. It rather demands creativity, intelligence, and imaginative capabilities (Einstein and Infeld 1938). Furthermore, even when using the same underlying scientific method, inquiry procedures can nonetheless vary in the different research fields. The scientific inquiry aims to be as objective as possible in order to reduce bias and dependencies of research teams or interpreters of the results. To ensure objectivity in research, scientific methods provide some principles including replicability, independence, precision, and falsification (Recker 2013). Herwix and Rosenkranz introduced the scientific inquiry framework in order to provide a generic view of scientific inquiry in the field of design science. They illustrate and describe the inquiry as a generic possibly highly iterative, complex, and nested process (Herwix and Rosenkranz 2018).

Using the principles of the scientific method, different research methods emerged and are applied by researchers in the quest for scientific knowledge. There exist many definitions of research methods in the literature. Bhattacherjee, for instance, describes research methods as a standardized set of techniques for building scientific knowledge on the principle that the process be logical, confirmable, repeatable, and scrutinizable (Bhattacherjee 2012). SAGE offers the following definition of the term "method" in the context of research: "Research methods are the systematic tools used to find, collect, analyze and interpret information." (SAGE 2020). Additionally, research methods provide activity or task descriptions that explain what has to be done to fulfill the above principles.

DSR is characterized by a pluralism of complementary research methods that are often combined with each other (Winter and Aier 2016). Each stage of a DSR project requires different methods and the selection depends on the research design of the project (Hevner et al. 2004). For example, in problem understanding, literature reviews are conducted as well as empirical research methods. In the design phase, formal methods such as conceptual modeling and programming are applied. For the evaluation phase Hevner et al., for instance, describe 12 different methods a design science researcher can apply depending on the evaluation strategy.

Within the design science paradigm, two different opinions emerged in the field of IS. One is the design theory camp (Gregor and Hevner 2013; Markus et al. 2002; Walls et al. 1992) the other a pragmatic design camp (Herwix and Zur Heiden 2022; Hevner et al. 2004; Nunamaker et al. 1990) with the former focusing more on design theory and the latter on the artifact as research contribution. Pragmatism has a strong influence on the modern philosophy of science and especially in behavioral research (Zettle et al. 2016). Skinner provides an example of pragmatic thinking in science with the statement that science is "a corpus with rules for effective actions" (Skinner 1957, p. 235). In this work, we use the nature of pragmatism as foundation to describe different research methods and the underlying processes.

2.2 Research Processes

Research methods are highly intertwined with processes and there are several definitions of research methods that describe the core of a method in terms of a process. For example, Nash considers the method to be "a technique or way of proceeding in gathering evidence" (Nash 1988). Research processes support researchers in generating new and testing existing knowledge by pursuing domain-driven research questions and applying valid research methods (Nunamaker et al. 1990). A process can be decomposed into a set of activities that are linked by a logical and temporal flow (Leist and Rosemann 2011). According to the latest BPMN 2.0 standard, an activity represents something that gets done (Allweyer 2016). This can be a single task or a compound activity that represents a collection of other tasks. Tasks are generally performed by humans or applications when they are executed. Process models have been found to be a key element of business process modeling capabilities of organizations in various contexts (Brocke and Rosemann 2015). Research process management has not been extensively researched in the past. In the literature, there exist different modeling approaches for research processes. First, authors using narrative text to describe the research process (Bonoma 1985). Second, authors using narrative text to describe the process supplemented by graphical process models illustrating specific activities (Hevner et al. 2004). Third, authors using entirely graphical representation from beginning to end of the process but without any underlying meta-model (Peffers et al. 2007). Fourth, introduced by Leist and Rosemann, using business process model notation and tools like ARIS to describe research processes. Furthermore, Leist and Rosemann applied a process-centered view on IS research methods and elaborated on basic concepts towards research process management in their work (Leist and Rosemann 2011). More recently, Mousavi Baygi et al. introduced the idea of flow-oriented approaches in research. They suggest shifting from actor-centered thinking towards temporal, processual, and flow-oriented approaches to increase the possibilities in theorizing and research practices (Mousavi Baygi et al. 2021).

Existing research emphasized the evolutionary nature of DSR (Markus et al. 2002) and its highly context-dependent and iterative research process (Herwix and Zur Heiden 2022). The literature provides different process models guiding design science researchers through different phases, for instance, Peffers et al. (2007) or Vaishnavi and Kuechler (2007), which suggest what kind of activities comprise a DSR project and how they would relate to one another. However, on the instantiation level, it is well understood that every single DSR project follows its own process taking into account specific opportunities and constraints of the design. Vom Brocke et al. propose journaling DSR activities in order to capture project-specific DSR process knowledge on the instantiation level (Brocke et al. 2021). Furthermore, there exist tools such as MyDesignProcess[1], which support design science researchers in documenting, structuring, and sharing of project-specific design activities on an instantiation level (Brocke et al. 2017). In this work, we use the term research process on the scientific inquiry level and define it as a well-defined sequence of activities or sub-activities described by a research method.

In other areas with different types of knowledge, tool support exists that enables common understanding and harmonized documentation of knowledge. An example is the Information Systems wiki on IS theories (K. R Larsen and Eargle 2020). They collect theories used or developed

[1] https://mydesignprocess.com

in the IS field and document them based on their conceptual model. Another example is DISKNET, which aims to provide structured and machine-processable knowledge on structural equation modeling (SEM) studies. The authors argue that such systems enable systematic knowledge accumulation and support building a consistent body of knowledge (Dann et al. 2019).

2.3 Open Science and Open Models

Open Science can be traced back to the Middle Ages when the first scientific association was established in 1660: The Royal Society of London for Improving of Natural Knowledge with a focus on openness and inclusion of women (Willinsky 2005). Since the rise of the internet and related new technologies, Open Science has been growing rapidly. The main objective of Open Science is to foster transparency, openness, and reproducibility (Stracke 2020). UNESCO describes the core of Open Science as built on four key pillars: open scientific knowledge, open science infrastructures, open engagement of societal actors, and open dialogue with other knowledge systems. Open science infrastructures refer to shared research infrastructures such as repositories or knowledge-based resources that support open science and serve the needs of different communities (UNESCO 2021). For instance, in the field of method engineering, OMiLAB aims to foster a community that can benefit from an open modeling environment focusing on modeling method engineering through metamodeling (Götzinger et al. 2016). OMiLAB provides tools to explore method creation and design as well as tools containing domain-specific conceptual models provided by the conceptual modeling community (Domain-Specific Conceptual Modeling 2022). Other examples of existing open infrastructure are repositories providing researchers and practitioners access to existing reference models. For instance, in the field of business process models, the Open Process Handbook Initiative[2] provides a collection of over 5000 freely available models of business activities created by a group of organizations and individuals. Though, the design of the available reference models is not transparent and open.

Inspired by the concept of open-source software, researchers suggest applying a community-driven collaborative modeling approach in order to increase the development and reuse of existing reference models. Furthermore, the authors state that open model development can lead to higher quality of models, increase usability and usefulness, enable knowledge exchange between researchers and practitioners, and promote the use of models in teaching and training (Frank and Strecker 2007). However, in the field of DSR there is a lack of design knowledge for tools to make reference models and design process descriptions accessible in a structured and harmonized way on an open repository for development and reuse.

3 Research Design

We follow a DSR process described by Kuechler and Vaishnavi (2008) aiming to deliver a solution for the real-world problem of providing an open DSR process knowledge repository supporting researchers. The work presented in this paper is embedded into a comprehensive DSR project, as illustrated in Fig. 1. We report the results of the two iterations conducted during our research project, focusing on DSR process modeling as part of the overall project on DSR process management.

DSR is an iterative process starting with the problem identification in the problem space and ending with the evaluation of different solutions in the solution space (Venable 2006). Most DSR projects are complex and conducted through various iterations (Brocke and Maedche 2019) including different research methods (Hevner et al. 2004). Such knowledge on research methods is disseminated via different sources. Additionally, research methods evolve and can have different levels of maturity or even give rise to new branches, and this information lacks explicit documentation. Hence, we discovered the need to provide a system where research methods and their processes

[2] http://ccs.mit.edu/ophi/main.htm

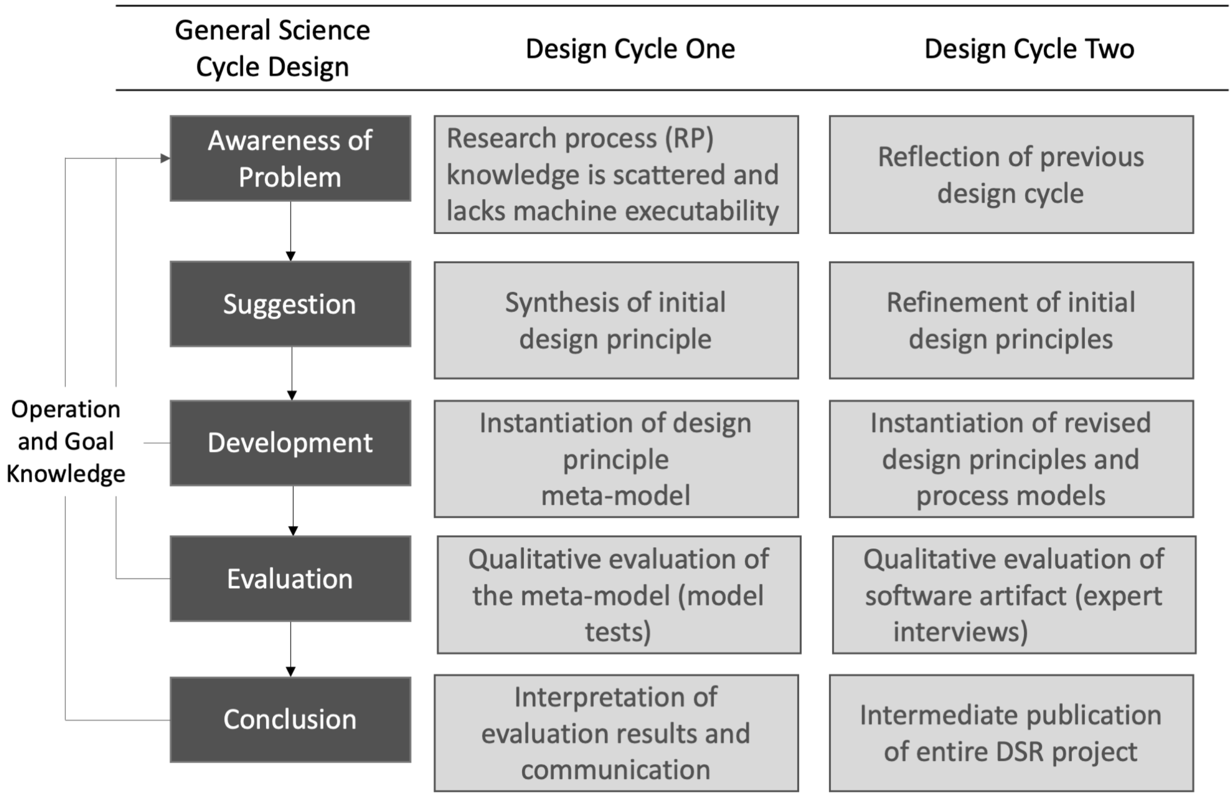

Figure 1: Overall Research Design

are described in a harmonized, structured way and in a form that makes the process knowledge manageable and reusable. In the first cycle, we identified several meta-requirements for research process modeling systems. We build on existing literature in the field of DSR and the theory of knowledge reuse (Markus 2001) to ground the meta-requirements. Based on those requirements, we derived an initial design principle focusing on designing a conceptual model for research process descriptions. Specifically, we designed and evaluated a meta-model to describe research processes. In the evaluation phase, we selected a set of research methods in the field of DSR and instantiated process models. The models were created in a generic modeling tool, which we tested against the meta-model by comparing the entities and relations.

In the second cycle, we extended on the meta-model from the first cycle and made it usable by designing and implementing a process modeling system based on the meta-model. The aim of this system is to integrate the meta-model and provide functions to capture and distribute process description knowledge used in DSR in order to reuse it. Using the theory of knowledge reuse, we extended our meta-requirements and design principles from the first cycle to conceptualize a DSR process modeling system. We instantiated the extended design principles and created instantiations of research process descriptions using the system. The evaluation is conducted by applying the model quality framework provided by Moody and Shanks (1994). To complete the second cycle, we collected feedback by interviewing modeling experts and design science researchers about the provided system and the process descriptions. The prototypical showcase will demonstrate the potential of the DSR process modeling system for supporting students and IS scholars in studying and reviewing scientific research methods.

4 Design Cycle One

4.1 Problem Awareness

There exist many approaches and process descriptions on how to conduct DSR projects (Morana et al. 2018). Furthermore, it is possible to apply different research methods in each phase of a DSR project. We recognized that knowledge about research methods is disseminated through different sources and described using a variety of formats and styles. Such unstructured knowledge is difficult to reuse and lacks machine executability. The primary objective of tools for supporting research process management in DSR is to collect existing research method knowledge in a structured way that allows other researchers to study, apply or further develop the existing research methods and the underlying processes and activities (Leist and Rosemann 2011). We apply the theory of knowledge reuse by Markus and follow the described knowledge reuse cycle. Her process illustrates knowledge reuse in terms of the following steps: capturing or documenting knowledge, packaging knowledge for reuse, distributing or disseminating knowledge (providing people with access to it), and reusing knowledge (Markus 2001). In the first cycle, we focus on the packaging of process knowledge for the purpose of knowledge reuse.

4.2 Meta-Requirements and Design Principles

In this section, we present several meta-requirements for a corresponding artifact grounded in prior literature. According to Markus, packing knowledge includes culling, cleaning and polishing, structuring, formatting, or indexing documents against a classification scheme (Markus 2001). Considering these basic assumptions, we first derive the following meta-requirements (MR).

MR1: The system must provide a classification scheme for research process descriptions.

Most research processes used in DSR provide researchers with a series of activities and tasks to follow in conducting their research. To create a common understanding of these processes and activities, a consistent data model describing those needs to be established (Leist and Rosemann 2011).

MR2: The classification scheme must meet the specific requirements of different processes used in DSR.

Building on the meta-requirements identified previously, we derive a first design principle for the modeling system. Design principles capture knowledge about instances of a class of artifacts (Sein et al. 2011). The suggested design principles fall into the category of action-/ user-oriented and materiality-oriented design principles, with a focus on what the tool should allow users to do (Chandra Kruse et al. 2015; Gregor et al. 2020).

Based on the requirements derived above, research process modeling systems must contain a prescriptive model to handle research method descriptions (Leist and Rosemann 2011). Correspondingly, the first initial design principle (DP) is:

DP1 (Principle of a conceptual model): Provide the system with a conceptual model in order to allow researchers describing DSR methods in a common way.

4.3 Meta-Model

Metamodeling is the analysis, construction, and development of frames, rules, constraints, models, and theories. These models are applicable and useful for modeling a predefined class of problems (Brinkkemper 1996). For example, meta-models have been utilized to represent the elements of methods in method engineering. Regarding DP1, we propose a meta-model as a common ground for modeling research methods, processes, and activities. The structure of research methods and the process descriptions are represented by the meta-model. Additionally, the meta-model serves as a foundation to conceptualize research process descriptions.

Inspired by existing conceptualizations in the form of meta-models (see Brinkkemper 1996, Bucher et al. 2007, Cossentino et al. 2010, and Kurpjuweit and Winter 2007), we propose a meta-model containing the following three main concepts: Method, Process, and Activity. The main concepts and their relations are illustrated in Fig. 2. A method describes a single or set of research processes that are similar or related to each other. Examples for such methods are literature review research (Brocke et al. 2009), focus group research (Tremblay et al. 2010), or design science research (Hevner et al. 2004). A process is a set of activities (usually taking place in a predefined order). Each method can contain one or more processes with different characterizations. One example would be the different approaches outlined in design science research literature (see Peffers et al. 2007, Sein et al. 2011, Kuechler and Vaishnavi 2008). Activities describe what has to be done in a specific process, such as the problem identification & motivation in the design science research process according to Peffers et al. (2007) or the definition of review scope as part of the literature review process (Brocke et al. 2009). Activities can also contain hierarchically structured sub-activities. Moreover, activities can have descriptions of examples, references to related literature, or an iteration linking to the previous activity in the process.

4.4 Evaluation

At the end of the first design cycle, we evaluated the meta-model that we derived as an intermediate artifact based on DP1. We followed the evaluation strategy for technical artifacts (Venable et al. 2016) and applied the meta-model to various real-world research methods to test it. We evaluated the meta-model by comparing it with requirements derived from the process descriptions in the literature. The objective was to test if the designed artifact closes the identified gap between the problem and the available solutions (Pries-Heje et al. 2008). Due to the generality of meta-models, it is almost impossible to evaluate every aspect and possible instance. Instead, selecting a set of potential instances is recommended (Sadilek and Weißleder 2008).

We created process models of the following processes, all of which are DSR approaches widely used in the IS field: Action design research according to Sein et al, DSR according to Kuechler & Vaishnavi, and DSR according to Peffers et al. Additionally, we created process models for the literature review method described by Brocke et al. (2009) and according to Webster and Watson (2002), as well for case study research following Ebneyamini and Sadeghi Moghadam (2018), single case study research, taxonomy development, and focus groups as described by Tremblay et al. (2010).

Based on the selected list, we instantiated test models of five different research methods with nine different processes including 60 activities. Fig. 3 illustrates an instantiation of the process model based on the description provided by Peffers et al. (2007).

We analyzed the models and compared the instantiations with the features of the meta-model. The tests included a comparison of the instantiated test model entities and relations with the meta-model entities and relations. For example, the above model describes the DSR (Method) approach of Peffers et al. (Process) including the steps (Activities) Problem identification and motivation, Objectives for a solution, Design and development, Demonstrate, Evaluation, Communication including several redesign iterations (Peffers et al. 2007), which can be mapped into the proposed meta-model. The results of the tests showed that all the above-listed processes can be modeled similarly to the described example of Peffers et al. and fit into the meta-model.

5 Design Cycle Two

5.1 Problem Awareness

In the second cycle, we focus on capturing or documenting knowledge and distributing or disseminating knowledge of process descriptions in design science research. We aim to design and implement a system that supports researchers in

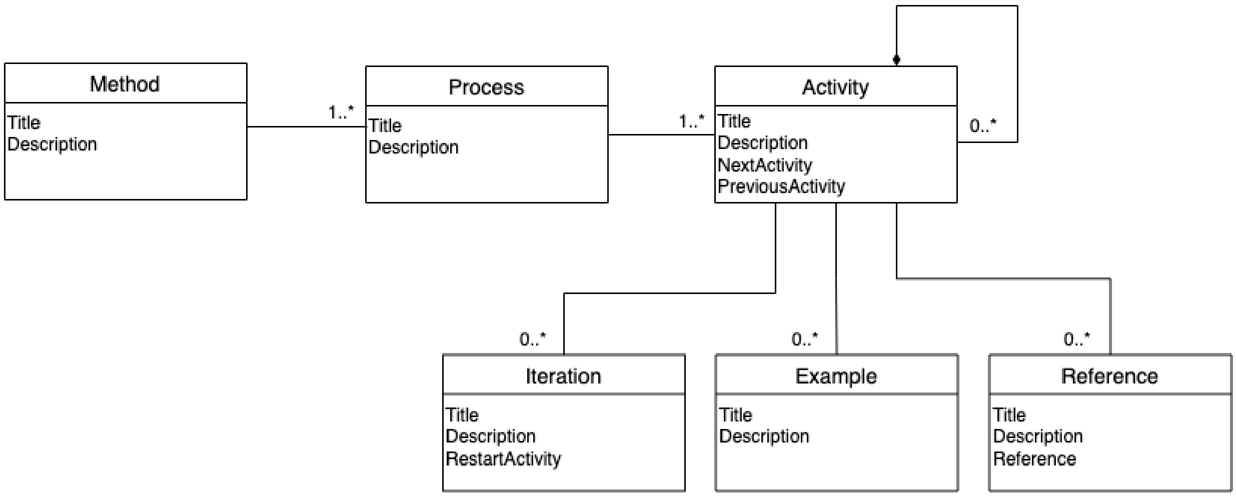

Figure 2: Meta-Model describing DSR research processes

collecting and describing existing research method knowledge in an open repository. We present a wiki-based research process modeling prototype in the form of a publicly accessible web platform. The data model of the process modeling system is based on the meta-model. Furthermore, the system should enable other researchers to study, apply, or further develop the existing research methods and the underlying processes and activities (Leist and Rosemann 2011).

We consider research process modeling to be a collaborative endeavor (Leist and Rosemann 2011), and we thus distinguish three key user roles: (1) the researcher modeling and documenting the research method; (2) interested researchers viewing the documented research process; (3) practitioners interested in selected research methods. Considering these basic assumptions and key roles, we derive meta-requirements (MR) first and then, based on the MR, derive design principles for research process modeling support systems.

5.2 Refined Meta-Requirements and Design Principles

In this section, we present several requirements for process modeling systems grounded in prior literature. Knowledge about research processes must be available through a user interface, and users must be able to create, store, retrieve, share, or perform other operations over explicit knowledge forms (Lucena et al. 2015). These operations serve as general requirements used in organizational knowledge management systems (Alavi and Leidner 2001).

MR3: The system must enable adding new and editing existing research process models.

An essential step in retrieving existing process descriptions is to define search strings (Markus 2001). Based on such search strings created by the user, the system can look up and deliver the stored knowledge.

MR4: The system must enable sharing of research process knowledge with other researchers.

Design science research relies on the application of multiple and different research methods. An example of this would be through constructing and evaluating design artifacts (Hevner et al. 2004). To support referencing of other process descriptions within a process description, the system must provide linking features to related process or activity descriptions. Such knowledge can either be already documented in the system or linked as an external resource.

MR5: The system must support linking of related internal or external process knowledge.

Ongoing, collaborative process-knowledge evolution is a simple and powerful instrument for keeping the process documentation up-to-date

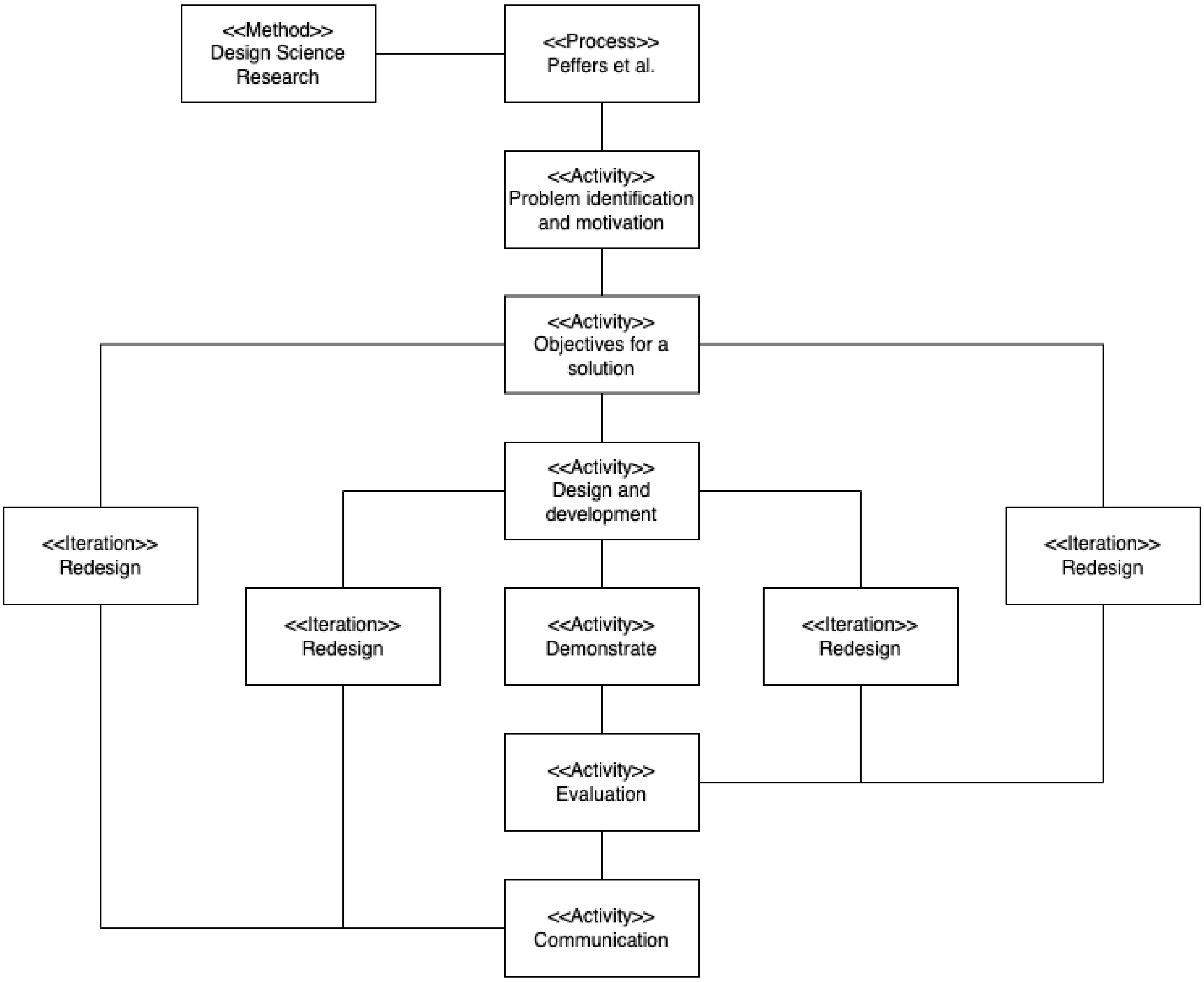

Figure 3: DSR process model instantiation based on the description provided by Peffers et al.

with respect to the actual state of the real-world process (Dengler et al. 2009). Thus, the system should provide support for collaborative process modeling with other researchers. This includes elements such as user management and tracking of changes in the models and descriptions.

MR6: The system must enable collaborative research process model development.

MR7: The system must support versioning of the modeling process.

Based on the previously identified meta-requirements, we derive a set of initial design principles for the system. Design principles capture knowledge about instances of a class of artifacts (Sein et al. 2011). The suggested design principles fall into the category of action-/ user-oriented and materiality-oriented design principles with a focus on what the system should allow users to do (Chandra Kruse et al. 2015; Gregor et al. 2020).

To manage research method descriptions, the system must provide features to create, store, modify, and delete the main constructs defined by the prescriptive method schema. The system must provide a corresponding user interface (Lucena et al. 2015).

DP2 (Principle of documentation): Provide the system with a user interface containing documentation features in order to allow researchers to create new method descriptions or further develop existing descriptions.

Existing and stored process descriptions must be accessible to other scholars in the IS field and beyond. This allows other researchers to study research processes and reuse the knowledge (Markus 2001).

DP3 (Principle of reuse): Provide the system with reuse features in order to allow researchers to access and study existing process descriptions.

5.3 Prototypical Implementation

In this section, we describe the prototypical implementation of the modeling system. We have instantiated the set of initially derived design principles introduced above by defining and mapping design features (DF) to the design principles. Design features are specific artifact capabilities describing abstract design principles (Meth et al. 2015). Tab. 1 describes the relationship between identified design requirements, the derived design principles, and the implemented design features from both cycles.

The modeling system is implemented as an open web-based application (DF7). The web application uses the open-source software MediaWiki[3] a well-known and widely adopted collaboration and documentation system used in documenting process knowledge (Dengler and Vrandečić 2011). Users can register at the platform and start contributing to existing process descriptions or add new process knowledge (DF5). MediaWiki provides for each page extensive revision functionality like watching, comparing, merging, reverting, and more to take track of changes and observe the evolution of the process description (DF6). Stored knowledge can be accessed easily by browsing through the database, following hyperlinks in the process description, or by using the search function (DF8, DF9).

We used the "category" feature of MediaWiki to implement the proposed meta-model. The different constructs Method, Process, and Activity are mapped as hierarchical structures and serve as navigation at the same time (DF2). Additionally, we make use of the "template" functionality and combine it with the "category" feature (DF1). If a user creates a new process variant of a method, the process template gets instantiated, and a set of empty activities are created under the new process hierarchy (DF3). Following the provided processes template supports researchers in documenting process knowledge in a structured way. A screenshot of the prototypical implementation is illustrated in Fig. 4. On the landing page, a research method can be selected. Subsequently, existing research process descriptions of the method will be displayed (DF4). By selecting one specific research process, the user gets a detailed overview of the described activities for the selected research process.

An illustration of different research processes in a specific research method is also shown in Fig. 4. In the case of the literature review, the prototype provides two different process descriptions. These are, namely, the processes described by Brocke et al. (2009), and the processes described by Webster and Watson (2002). By selecting one specific process, the activity descriptions of the selected process will be displayed.

While documenting research processes or activities, the system provides predefined templates that can be used at any time. We defined templates following the structure of the meta-model. Such templates contain an empty skeleton for process description, as illustrated in Fig. 5, or an empty activity description. The system provides predefined templates for reuse as well as allowing the creation of user-specific templates to enhance the template database.

Fig. 6 illustrates an example of the 'Evaluation' activity taken from the DSR process described by Peffers et al. (2007). The activity contains a general activity description, examples referring to other process descriptions, additional references for further readings, and two iteration possibilities to related activities in the research process description.

[3] https://www.mediawiki.org/

Requirement	Design Principle	Design Features
MR1, MR2	DP1: Principle of a conceptual model	DF1: Research process knowledge description templates DF2: Hierarchical structure of process knowledge description
MR3, MR6, MR7	DP2: Principle of documentation	DF3: Unified process knowledge description representation DF4: Aggregation of different processes of the same method DF5: Register to become an editor DF6: Tracking of process knowledge description changes
MR4, MR5	DP3: Principle of reuse	DF7: Open access to process knowledge DF8: Process knowledge search function DF9: Linking of related process knowledge description DF10: API to access process knowledge description

Table 1: Design principles and their relation to the identified requirements and the implemented design features

5.4 Evaluation

In the second cycle, we evaluated the quality of the meta-model following the framework for evaluating and improving the quality of entity-relationship models outlined by Moody and Shanks (1994). We also evaluated the proposed design principles through evaluation of their instantiation using semi-structured interviews according to Myers (2019).

5.4.1 Method

To evaluate the meta-model, we applied the evaluation framework for improving the quality of data models developed by Moody and Shanks. Their framework consists of five components: stakeholders, quality factors, quality measures, weightings, and improvement strategies. Furthermore, the framework provides seven quality factors as criteria for evaluating data models, including measures for each. These quality factors define an overall picture of data model quality and incorporate the perspectives of all stakeholders (Moody and Shanks 1994). The quality factors of the framework and its measures are summarized in Tab. 2.

Regarding Venable et al., we follow an ex-post evaluation done in a naturalistic setting. This has several advantages, one being that it deals with real users and problems (Venable et al. 2012). We applied the meta-model quality framework and conducted interviews with selected experts in the field. An overview of the interviewees and their skills are summarized in Tab. 3.

Following Myers, we developed an interview guideline, including several opening and open-ended questions, before conducting the interviews (Myers 2019). The opening questions asked for information regarding demographics, profession, and experience in using research methods in DSR. The open-ended questions addressed the quality factors of the evaluation framework as well as challenges that emerge throughout the design process of DSR projects. Before conducting the interviews, we provided the participants with a

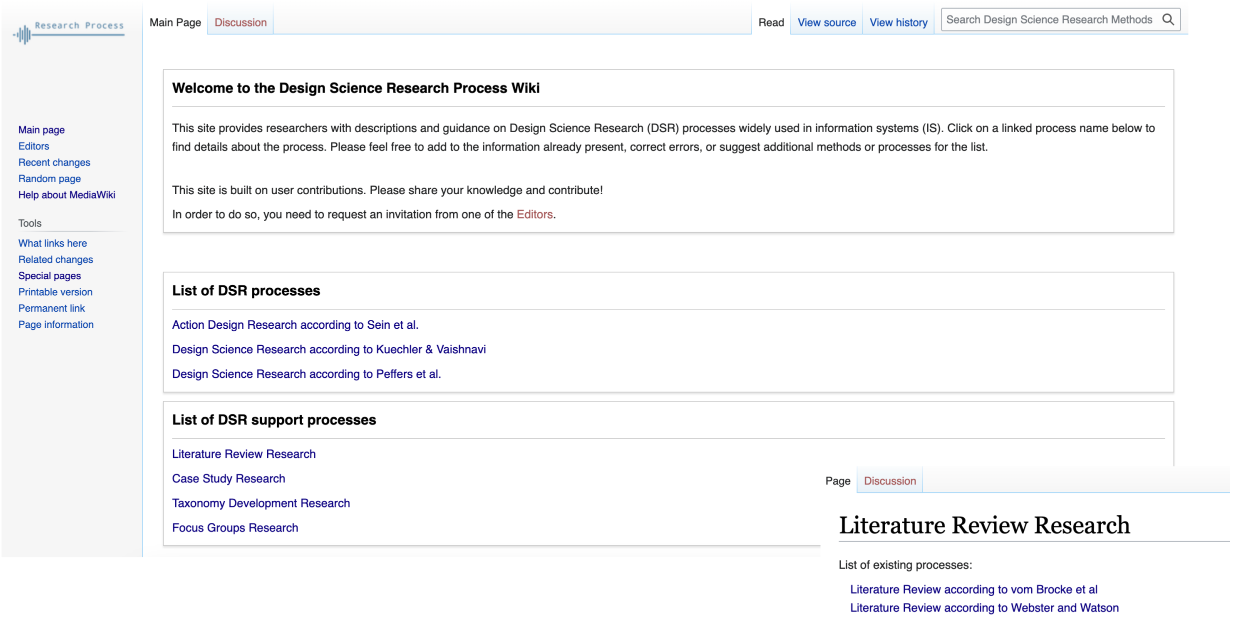

Figure 4: Screenshot of the prototype

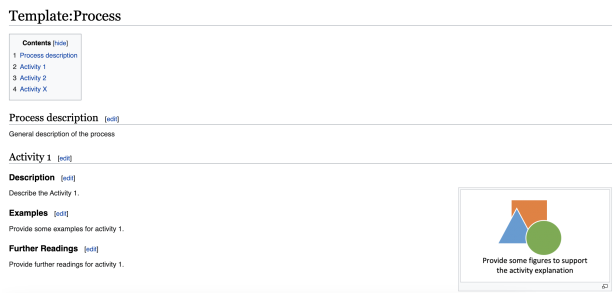

Figure 5: Research process description template

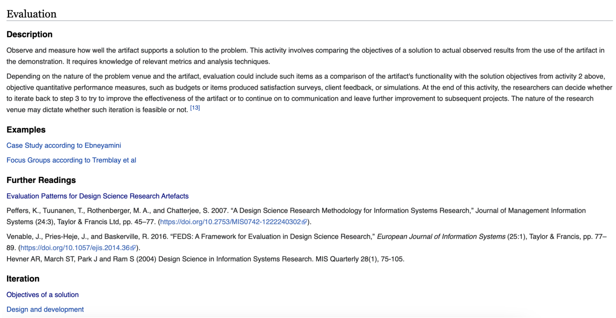

Figure 6: Example of a research activity description

link to the wiki containing an initial set of process descriptions derived from the first cycle and asked them to familiarize themselves with the system and the captured process knowledge. During the interviews, we first demonstrated the wiki as an instantiation of the design principles and demonstrated the implemented design features and the underlying simplified meta-model. Each interviewed researcher then selected a DSR research process model described in the wiki she or he was familiar with, and we applied a scenario analysis. Scenario analyses are an effective way to test if users can understand the model and the concepts in order to apply them correctly (Moody and Shanks 1994). We demonstrated to the interviewees the model instantiation of the selected process and asked open questions based on the quality factors suggested by the evaluation framework: completeness, simplicity, flexibility, and understanding (see Tab. 3). We also allowed for flexible adjustments based on the interview responses. Each interview session was conducted over a virtual meeting using Zoom and was audio recorded. The average duration of the recordings was 26 minutes.

Quality Factor	Definition	Used Quality Measures
Correctness	"Does the model conform to the rules of the data modeling technique being used?" (Moody and Shanks 1994)	CASE Tool, Modeling Expert
Completeness	"Does the model contain all information required to meet user requirements?" (Moody and Shanks 1994)	Design Science Researcher (Scenario Analysis)
Simplicity	"Could the requirements be represented using fewer entities and/or relationships?" (Moody and Shanks 1994)	Modeling Expert, Design Science Researcher (Scenario Analysis)
Flexibility	"How well can the model cope with future changes in requirements?" (Moody and Shanks 1994)	Design Science Researcher (Scenario Analysis)
Integration	Is the data model consistent with the rest of the organizations' data?" (Moody and Shanks 1994)	Not evaluated. Integration is not relevant in our case.
Understandable	"How easily can the model be understood?" (Moody and Shanks 1994)	Modeling Expert, Design Science Researcher (Scenario Analysis)
Implementability	"Can the data model be implemented within the time, budget and performance constraints of the project?" (Moody and Shanks 1994)	Modeling Expert

Table 2: Model Quality Factors according to Moody and Shanks Evaluation Framework

5.4.2 Results

We interviewed researchers in the field of DSR with different levels of experience in applying DSR methods. Furthermore, we selected senior system architects working in the industry with modeling experience to evaluate the meta-model. In total, we conducted a series of eight semi-structured expert interviews in Europe.

After we conducted the interviews, all audio recordings were transcribed into text. Next, we imported the text files into Atlas.ti, a qualitative data analysis tool, and coded the answers following the coding stages provided by Corbin and Strauss (2014). The interviews and the coding were done by the authors. In the following, we describe the results of each quality factor of the evaluation framework provided by Moody and Shanks and the results of the coding.

Correctness. We used the CASE tool Er-Builder (Softbuilder 2021) and its internal model validation checker and applied it on the meta-model. The validator detected zero errors and zero warnings. The modeling experts also confirmed the results of the CASE tool checker.

Completeness. All design science researchers agreed on completeness. None of the researchers

ID	Profession	Working Experience	Age
R1	Enterprise System Architect	10 Years	41
R2	Web Application Architect	17 Years	37
R3	Design Science Researcher	2 Years	26
R4	Design Science Researcher	1 Years	24
R5	Design Science Researcher	3 Years	27
R6	Design Science Researcher	7 Years	33
R7	Design Science Researcher	5 Years	29
R8	Design Science Researcher	6 Years	32

Table 3: Summary of interviews experts

and experts identified missing entities or relations. One researcher stated: “All the methods and approaches I know in DSR can be expressed using the meta-model”. The other researchers gave similar responses.

Simplicity. One modeling expert mentioned that “The meta-model is very easy and hence arguably not sophisticated enough”. However, he could not specify any concrete issues regarding simplicity.

Flexibility. None of the researchers could think of a problem with upcoming methods or processes in DSR. One researcher argued: “If a new method is not process-oriented, the model would not fit anymore”. Having said that, he also added: “All methods I know are process-oriented so far”.

Understandable. All interviewed researchers and experts agreed on the simplicity of the model. It is simple and easy to understand, and one comment was: “Anyone who understands entity-relationship (ER) models will be able to understand the meta-model” or another comment was, “As an information system researcher we should be able to understand such models.”

Implementability. All modeling experts agreed on the implementability of the meta-model. One expert commented, “circular references might be an issue and has to be considered in the implantation”.

We found evidence in the interview data that the knowledge reuse principle provided by the wiki was perceived as useful. The interviewees agreed that the research process knowledge can be reused and applied in future research. Furthermore, the additionally provided examples and references are perceived as very useful. The following are examples of comments by design science researchers: “Especially as a beginner, the wiki is a good entry point to get knowledge about design science research methods and processes,” “I like to jump forward and backward or to other process descriptions,” “The provided process descriptions are useful to get an overview without reading the complete papers,” and “The wiki would have helped me in the beginning of my PhD.”

We also found evidence in the interview data that conceptual modeling of research process modeling was perceived as useful. The interviewees confirmed that the presented models in the wiki are described correctly and are complete with respect the original source. For instance: “The descriptions are correct and complete”, “I like the fact that the descriptions provide additional examples and further literature”, “The descriptions are short and concise but also informative”, “Based on the provided description there is no need to read the process described in the original paper”, and “I liked that the links to the original sources are provided to get more details if needed”.

Finally, we found evidence in the interview data that the principle of research process documentation was perceived as useful. The interviewed researchers emphasized the power of the central storage and the possible advantage of providing a comprehensive overview of research methods used in the field of DSR. They agreed with the following statements: “I like the wiki and it has many advantages to describe research processes”, “The wiki is very useful to get an overview of the different research methods used in DSR” and “I like the fact that it is publicly available”.

Based on the coded answers, 87% of the interviewees reported that the provided process descriptions are easy to read. Furthermore, 67% of the interviewed DSR researchers perceived the additional literature we provided in the wiki as useful. 67% stated that the wiki is useful for novice researchers and students, and can serve as an entry point to study DSR approaches. 67% said there is no need to read the full paper in order to understand the process of a research method based on the descriptions in the wiki. 67% said that the meta-model would also be appropriate for research methods used outside the IS field. 50% liked the additional examples we provided in the wiki. 33% said that the wiki provides a good overview of existing method knowledge in DSR.

When asked for additional thoughts, a design science researcher suggested: “It would be nice to provide some templates for each process that can be filled out by a researcher, like a canvas”. Another researcher noted: “Information about possible outlets to publish design science research or method-specific research projects would be interesting” or adding information such as “... problems or limitations of a specific process”, and “Which method fits best for which class of problem” would be helpful.

6 Discussion

In this paper, we report on our DSR project to build tool support for representing research process knowledge in design science research. We aim to develop a DSR process modeling system that allows DSR scholars to make existing process knowledge accessible on an open repository for reuse and evolution. The meta-model supports semi-formal process modeling to describe DSR process knowledge in a structured manner. Additionally, it serves as conceptualization of DSR process knowledge and describes the core concepts of research methods and their relations. Furthermore, we present three design principles for DSR process modeling systems and a prototypical instantiation of the design principles applying the meta-model.

Through this effort, we hope to provide capabilities that will support researchers to make relevant research processes and their characteristics visible and less cumbersome (e. g., by providing a comprehensive list of different research methods and their different approaches and by providing relevant knowledge to conduct the processes). Furthermore, less experienced design science researchers, such as students or doctoral researchers, can benefit from a central, structured, and comprehensive DSR knowledge base: For instance, the given overview of methods and process descriptions can serve as an entry point in teaching and education to study the different DSR approaches and the underlying processes as suggested by Frank and Strecker (2007). We instantiated the proposed meta-model in a web-based and widely used MediaWiki in order to provide open access to the models and process descriptions. Moreover, compared to open modeling environments such as OMiLAB (Götzinger et al. 2016) the wiki also serves as an open repository facilitating access to existing models and process descriptions to researchers and practitioners in the field of design-oriented research and beyond. Compared to other existing open process platforms, for instance, the Open Process Handbook[4] , the proposed system enables other researchers to edit existing or create new process model descriptions. Moreover, the system provides a web-based editor including templates to create new models, and no modeling skills are required to add new process descriptions. Similar to the approach of the open IS theories repository provided by K. R Larsen and Eargle (2020) we aim to collect and share research process descriptions supporting design science researchers.

[4] http://ccs.mit.edu/ophi/main.htm

While our work has great potential for the progress of our discipline, it also has some limitations. We will extend into further design cycles beyond the two discussed in this paper. We are aware that technology will play an enabling but only partial role in supporting knowledge accumulation and evolution of research methods. According to the business process management literature, for instance, further elements of importance also include governance structures as well as cultural values, to name but a few (Brocke and Rosemann 2015). Furthermore, the current prototypical implementation contains an initial set of nine different research process descriptions and the evaluation of the modeling system is limited to a total of eight researchers. To further elaborate on the capability of the system and the underlying conceptualization of research process descriptions, additional process models need to be added and evaluated by applying alternative methods. One such example would be the applicability checks following Rosemann and Vessey (2008). Future research will account for these limitations and wider capability areas, aiming for a social-technical ensemble of multiple contributions.

Additionally, the success of platforms using user-generated content such as wikis is highly dependent on the community efforts and the quality of the content. For instance, we are currently reflecting on governance frameworks suitable for our community to involve research method experts in the IS discipline. Thinking in terms analogous to the governance structures of our journals, there could be an argument for introducing senior editors for respected research methods to provide leadership in how to represent contributions on research methods and processes on the collaborative site. The senior method editor would invite a set of research process editors to provide descriptions for the activities that correspond to their expertise. It will be important to learn from input and early feedback from the community in order to ensure the overall structure is flexible enough to adjust as we proceed with the project and learn from our experiences.

We released a first version of the research process modeling system in combination with initial descriptions of DSR methods and the underlying processes accessible on the open repository https://wiki.mydesignprocess.com. Providing such a research process modeling system on an open repository will not only make research methods more accessible for colleagues and thus further foster diversity and quality of our research. It will also allow the further development of existing and emergent research methods and processes, thereby contributing to the adaptability of our field. Collective improvement can lead to complete and accurate research method descriptions. Furthermore, it supports further development, as well as the acceptance by other researchers of methods and the underlying processes. In the long run, we believe in particular that our approach and the system will contribute to further increasing research method maturity in DSR and beyond. DSR process execution systems like MyDesignProcess and similar can also benefit from the proposed meta-model and the open repository providing research process models—for example, by implementing the meta-model in the MyDesignProcess system and providing the research process model descriptions to support and guide users during their DSR project execution.

7 Conclusion

In this design science research project, we presented an approach and an open repository enabling the representation of DSR process knowledge to advance the accessibility and further development of DSR methods. Following the DSR process described by Kuechler and Vaishnavi (2008), we reported on two design cycles and delivered: 1) meta-requirements for a DSR process modeling system, 2) initial design principles based on the meta-requirements, 3) a meta-model for research process conceptualization, 4) instantiation of the meta-model embedded in a light-weight collaborative modeling system, and 5) report on the evaluation results. We evaluated the meta-model by using Moody and Shanks (1994) data model quality framework and assessed our design principles by interviewing design science researchers in the Information Systems field. Our evaluation results show that structured documentation of research processes is perceived as useful for sharing and reusing design process knowledge. Furthermore, we deliver an online repository, which is readily accessible for any kind of researcher. The repository provides a foundation to better access and further develop DSR methods. It also sets a foundation for future research to further investigate tool and platform development for knowledge sharing and collaboration in DSR. Further, the repository also makes a start in providing an overview of DSR methods available in the field of IS. We, therefore, invite fellow researchers to complement the repository by adding further process descriptions drawing on their own knowledge and experiences in DSR research.

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Appendix A: Interview Guide

Part0: Research method expertise

Q0.1: How many years of experience do you have in using research methods?

Q0.2: What is the research method you mainly apply in your research?

Part1: DSR process description review

Q1.1: Are the research process descriptions in the wiki correct, what needs to be improved or fixed?

Q1.2: Are the research process descriptions in the wiki complete, what is missing and needs to be added?

Q1.3: What else do you think would be helpful to understand research processes and the underlying activities better?

Q1.4: Can you elaborate on the usefulness of the described research processes based on the conceptual model provided by the wiki?

Part2: Process model review

Q2.1: How easily can the selected model be understood?

Q2.2: Does the model contain all information required to describe the selected research process?

Q2.3: How well can the selected model cope with future changes in the research method?

Q2.4: How well can the meta-model cope with

other design science research methods?
Q2.5: How well can the meta-model cope with other research methods?