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Evaluation Patterns for Design Science Research Artefacts

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Abstract. Artefact evaluation is regarded as being crucial for Design Science Research (DSR) in order to rigorously proof an artefact's relevance for practice. The availability of guidelines for structuring DSR processes notwithstanding, the current body of knowledge provides only rudimentary means for a design researcher to select and justify appropriate artefact evaluation strategies in a given situation. This paper proposes patterns that could be used to articulate and justify artefact evaluation strategies within DSR projects. These patterns have been synthesised from priorDSR literature concerned with evaluation strategies. They distinguish both ex ante as well as ex post evaluations and reflect current DSR approaches and evaluation criteria.

Keywords: Design Science Research, Evaluation, Artefact, Patterns

1 Introduction

Design science research (DSR) in information systems comprises of two primary activities: build and evaluate (cf. [1]). Although the evaluation of DSR artefacts as well as of design processes is regarded as being "crucial" [2, p. 82] much of the contemporary information system DSR work focuses on the build activity. Moreover, while design researchers could choose from a rich set of available evaluation methods frequently applied in the information systems (IS) or computer science (CS) discipline, current literature on DSR provides little guidance about how to choose strategies and methods for evaluation in DSR [3, p. 1]. Only recently some initial frameworks have been proposed to help articulating and selecting DSR evaluation strategies [3], [4]. However, the current body of knowledge provides only rudimentary means for a design researcher to select and justify appropriate artefact evaluation strategies in a given situation.

It is the aim of this paper to identify DSR evaluation patterns that can be observed within the DSR literature based on a synthesis of related work. These patterns shall inform design researchers in both the computer science as well as the information systems discipline. Retrospectively, different design activities have been emphasized in the past by both the CS or IS community. While computer scientists focus more on the build activities and technological rigor, IS researchers aimed at understanding the impact of IT artefacts on organizational elements (thus emphasising evaluation activities). Design science as a research paradigm integrates both perspectives [5]. The patterns proposed in this paper serve to guide design researchers from either the CS or IS discipline to structure and justify their DSR evaluation strategies.

The paper proceeds as follows. The next section reviews related work on evaluation in DSR by (1) discussing the general structure of a DSR process, (2) presenting sets of DSR evaluation criteria, (3) and describing existing DSR evaluation frameworks. The paper then synthesizes the related work and presents selected DSR evaluation patterns. The paper concludes with a summary of the findings and an outlook on future research.

2 Related Work

2.1 DSR Methods and Implied Evaluation Strategies

To date, a variety of approaches for conducting design science research have been proposed which basically imply a process that includes two high level activities: *build* and *evaluate* [1]. A prominent example of such a DSR process is provided by PEFFERS ET AL. [6]. Their DSR methodology has been synthesised from prior DSR process proposals by other authors in the field and is depicted in Fig. 1.

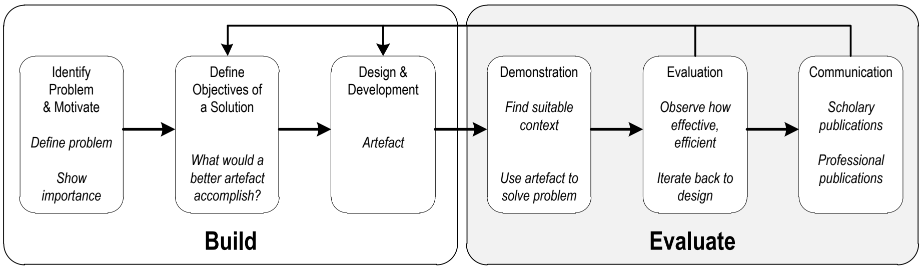

Fig. 1. Build and evaluate activities within a DSR methodology [cf. 6]

What can be seen from Fig.1 and what is also a typical assumptionofother DSR processes is that evaluation activities occur ex post, i.e. after an artefact is constructed [3]. In particular, existing DSR methods are characterised as “stage-gate-models” [7], explicitly separating evaluation activities from build activities and even emphasising the build activities over evaluation activities [7]. This separation has implies that technological rigor is valued more than organizational relevance [cf. 7].

As a response to these shortcoming SEIN ET AL. [7] propose a DSR method that suggests to conduct build and evaluate activities concurrently to immediately reflect the progress achieved and to trigger artefact revisions early within a design process. The concurrent evaluation accounts for the fact that artefacts “emerge” through the interaction with the organizational context as well as through design interventions, i.e. through reflection and learning activities [cf. 7].

The patterns proposed in this paperalso account for the emerging nature of DSR artefacts. Theyalso reflect common DSR evaluation criteria as well as existing frameworks for structuring DSR evaluation strategies. Both, evaluation criteria as well as evaluation frameworks will be presented in the following sections.

2.2 Artefact Evaluation Criteria

Evaluation in DSR aims at determining the progress achieved by designing, constructing, and using an artefact in relation to the identified problem and the design objectives [cf. 8], [1]. To systematically show if such a progress is achieved evaluations should be guided by *evaluation criteria* [cf. 8].Table 1 below lists DSR evaluation criteria proposed by MARCH & SMITH [1].

Table 1. Evaluation criteria for DSR artefacts [1]

	Construct	**Model**	**Method**	**Instantiation**
Completeness	X	X		
Ease of use	X		X	
Effectiveness				X
Efficiency			X	X
Elegance	X			
Fidelity with real world phenomena		X		
Generality			X	
Impact on the environment and on the artefact's users				X
Internal consistency		X		
Level of detail		X		
Operationality			X	
Robustness		X		
Simplicity	X			
Understandability	X			

While this set of DSR evaluation criteria is considered being comprehensive [8], however, the proposed evaluation criteria are not independent of the artefact type under consideration. AIER & FISCHER [8] suggest criteria that are independent of an artefact type and particularly apply for evaluating design theories. These criteria are [8]: *utility*, *internal consistency*, *external consistency*, *broad purpose and scope*, *simplicity*, *fruitfulness of further research*. These criteria can be mapped to at least one criteria proposed in [1] (see [8]). Another set of evaluation criteria is proposed by ROSEMANN & VESSEY [9]. Their criteria set aims at particularly ensuring the relevance of a DSR artefact, i.e. if an artefact is applicable in practice. The considered criteria are: *importance*, *suitability*, and *accessibility* of an artefact [9].

When choosing evaluation criteria a design researcher should pay attention to balance the interests of practitioners and researchers [cf. 8] which is a central aim of design science research. E.g. practitioners are interested in the applicability and usefulness of an artefact (relevance) whereas researchers are interested in the validity of the artefact and thus aim at structuring their evaluations appropriately in order to ensure rigour in the process.

2.3 Frameworks for Structuring DSR Artefact Evaluation Strategies

According to PRIES-HEJE ET AL. [3, p. 4] little work addressed the choice of strategies and methods in DSR evaluations. As a response to this identified gap they propose a framework to help researchers building evaluation strategies (normative application) or explicating unstated evaluation strategies in existing DSR literature (descriptive application) [4]. Their framework distinguishes evaluation strategies along three dimensions: (1) *what to evaluate* (design process or design product), (2) *when to evaluate*, and (3) *how to evaluate*.

Regarding the "*when*" dimension PRIES-HEJE ET AL. [3, p. 6] emphasise that "evaluation is not limited to a single activity conducted at the conclusion of a design-construct-evaluate cycle". Typically, evaluations in information systems and in particular in design science research can be conducted at two points in time relative to the artefact construction [7]: (1) *ex ante* where artefacts are evaluated prior to their implementation or actual construction, and (2) *ex post* where artefacts are evaluated after they have been designed and constructed [3, p. 5]. Depending upon how a design researcher chooses to define an actual artefact the ex ante – ex post distinction could possible slide [3].

Besides the point in time an evaluation is considered a design researcher must also decide *how* to evaluate an artefact. Referring to the work of VENABLE [8], PRIES-HEJE ET AL. [3] identify two primary forms of evaluation approaches in DSR: *artificial* and *naturalistic* approaches. Artificial evaluation judges an artefact in a "contrived and non-realistic way" [3, p. 4]. They hold that artificial evaluations (in [4] this is referred to as *evaluation against research gap*) are unreal. As a consequence, results gained through artificial evaluations may not be applicable to real use and thus have to be complemented by naturalistic evaluations which are conducted within an organization. Naturalistic evaluations are critical to ultimately proof the artefact's utility for practice [2] and thus have to be part within any DSR project.

However, it has been criticised that existing DSR methods envision naturalistic evaluations late in the research process and do not account for the fact that artefacts emerge through interaction with organizational elements [7]. Moreover, existing DSR methods provide only limited guidance on how to incorporate the organizational context into evaluations and what organizational elements should be reflected. Stemming from the IS evaluation literature, SUN & KANTOR [10] propose to structure evaluations according to the "realities", i.e. organizational elements, considered. They refer to a "three-realities" paradigm that encompasses (1) *real users*, (2) *real systems*, and (3) *real problems* as evaluation realities. Moreover, they consider three levels of granularity at which the results of using an information system may be judged: (1)

individual item retrieved, (2) *task completion*, and (3) *impact of the completed task on the motivating goal* of the individual or organization.

Artefact evaluations could incorporate the organizational contextboth partially or "entirely". Naturalistic evaluations (in [4] this is referred to as *evaluation against real world*) reflect all realities and involve real users using real systems to accomplish real tasks in real settings [3, p. 4].

Another, more general framework has been proposed by CLEVEN ET AL. [4]. In addition to the "what", "when" and "how" dimensions they consider further dimensions (12 in total), e.g. "artefact focus", "artefact type", "ontology", "epistemology", "reference point", or "function of an evaluation". The purpose of their framework is to explicate relevant dimensions (referred to as design variables by the authors, cf. [4]) to structure and configure DSR artefact evaluations and design processes. For an explanation of these additional dimensions we refer to the work of [4]. Compared to the work reported in [3] the framework explicitly lists evaluation methods, however, these are not classified, e.g. into observational, analytical, experimental, testing, or descriptive methods (like in [2]), or into artificial or naturalistic evaluation methods like in [3]. Furthermore, guidelines are missing with regard to how, and why to use a particular method. The patterns proposed in this papershall provide such guidance for researchers.

Dimensions	Characteristic Values					Source
Time	Ex Ante	Ex Post				[3]
Ontology	Realism	Nominalism				[4]
Epistemology	Positivism	Interpretivism				[4]
Perspective	Economic	Deployment	Engineering	Epistemological		[4]
Position	Externally	Internally				[4]
Function	Knowledge Function	Control Function	Development Function	Legitimization Function		[4]
Artefact Focus	Technical	Organizational	Strategic			[4]
Artefact Type	Construct	Model	Method	Instantiation	Theory	[4]
Method	Artificial	Naturalistic				[3]
	Assertion	Laboratory Experiment	Case Study	Field Study		[4]
	Simulation	Field Experiment	Action Research	Survey		
	Criteria-based Analysis	Theoretical Argument	Ethnography	Phenomenology		
	Mathematical Proof	Prototype		Hermeneutic Methods		
Realities Considered	Real Task	Real User	Real System			[10]
Level of Evaluation	Item Received	Completed Task	Impact of Task Completion			[10]

Fig. 2. Framework synthesis of DSR evaluation strategy dimensions

The morphological field in Fig.2 synthesizes the frameworks proposed in [3] and [4] and also reflects the "three-realities" as suggested in [10]. It shows the dimensions that have been considered being relevant for DSR artefact evaluations by other authors. In particular, a design researcher might choose from the dimension set to structure and configure particular evaluation strategies [cf. 3]. Since individual dimensions and their characteristic values could be correlated some configurations might emerge "naturally" in a given evaluation context. Such configurations can be generalized into *DSR evaluation patterns*. The next section presents selected patterns that reflect DSR processes structures, evaluation criteria, and evaluation strategies.

3 Evaluation Patterns

3.1 General DSR Evaluation Pattern

It has been criticised that current DSR processes strictly sequence build and evaluate activities and particularly envision the evaluation of an artefact late in the process (see discussion above). The DSR evaluation patterns described below address this limitation and aim at accounting for the emergent nature of DSR artefacts.

Fig. 3 below shows a cyclic high level DSR process including the activities *problem identification*, *design*, *construction*, and *use*. Furthermore, Fig. 3 suggests that each DSR activity is followed by an evaluation activity. Depending on when an evaluation occurs, *ex ante* as well as *ex post* evaluations are distinguished. Ex ante evaluations are conducted *before the construction* of any artefacts, ex post evaluations occur *after the construction* of any artefact [3].

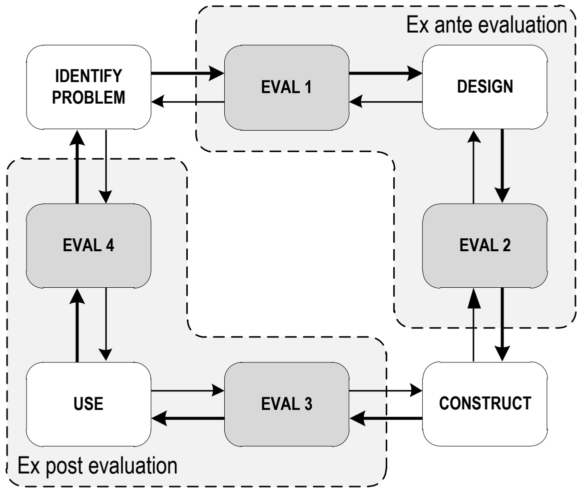

Fig. 3. Evaluation activities within a DSR process

The DSR process in Fig. 3 indicates that there are feedback loops from each evaluation activity to the preceding design activity. Overall, these feedback loops together form a feedback cycle that runs in the opposite direction as the DSR cycle.

The evaluation activities in Fig. 3 have been given generic names. Depending on the context and the purpose of an evaluation within the DSR process different evaluation methods or patterns [cf. 11] could be applied when conducting individual evaluation activities. Moreover, individual evaluation activities could be combined to form composite evaluation patterns. In this case the evaluation activities are highly integrated. An example of such a composite pattern is the Action Design Research method proposed by [7] that links build and evaluation activities by means of principles. Such composite patterns are not discussed here. Instead, the nature of the generic evaluation activities depicted in Fig. 3 is discussed below.

Eval1 Activity:
The evaluation of the problem identification activity serves the purpose of ensuring that a meaningful DSR problem is selected and formulated. It should be demonstrated whether the envisioned design problem is important for practice, is novel and thus represents a research gap, or results from the inability of existing artefacts to accommodate a new environment or context. The following methods could be applied:

- Assertion
- Literature review (identify critical issues studies, research gaps, or existing artefacts)
- Review practitioner initiatives
- Expert interview (not listed in Fig. 2)
- Focus groups (not listed in Fig. 2)
- Surveys

All methods finally serve to justify the engagement in a DSR project. Thus, the pattern pertinent to the Eval1 activity is termed *Justify*.

Eval2 Activity:
The evaluation of the design activity result serves the purpose of showing that an artefact design ingrains the solution to the stated problem. Since the artefact has not yet been constructed and thus not been applied this evaluation is artificial. Possible design criteria pertinent to this evaluation activity are *feasibility*, *accessibility*, *understandability*, *simplicity*, *elegance*, *completeness*, or *level of detail*. The following methods typically apply to this activity:

- Assertion
- Mathematical proof
- Logical reasoning
- Demonstration – Ex ante
- Simulation
- Benchmarking [cf. 11]
- Expert interview
- Focus group

The patterns pertinent to the Eval2 activity can be termed *assertion*, *demonstration*, *simulation*, and *formal proof*. The first two patterns are discussed in more detail below.

Eval3 Activity:
This evaluation activity serves to initially demonstrate if and how well the artefact performs while interacting with organizational elements. In this activity, some inferences on the utility of an artefact could already be made. Since this activity links ex ante as well as ex post evaluations of an artefact it is central for reflecting an artefact design and thus to initiate and inform subsequent iterations of the artefact

design activity (see feedback loop in Fig. 3). Both artificial, as well as naturalistic evaluation methods can be applied here. Thus the “realities” considered here may comprise subsets of “real tasks”, “real system”, and “real users”. Prototypes are frequently used at this stage. Possible design criteria may comprise *feasibility*, *ease of use, effectiveness, efficiency, fidelity with real world phenomenon*, *operationality, robustness*, or *suitability*. The following methods could be applied:

- Demonstration with prototype
- Experiment with prototype [cf. 11]
- Experiment with system [cf. 11]
- Benchmarking [cf. 11]
- Surveys
- Expert interview
- Focus group

The patterns pertinent to the Eval3 activity can be termed *prototyping* and *experimentation*. Prototyping will be discussed below.

Eval4 Activity:

This evaluation activity serves to ultimately show that an artefact is both applicable and useful in practice. Also, researchers might want to theorize on the design principles underlying the artefact. Only naturalistic evaluations will be applied here, i.e. the organizational context is reflected by means of all “three realities” (see discussion above). Possible design criteria pertinent to this evaluation activity are *applicability*, *effectiveness*, *efficiency*, *fidelity with real world phenomenon*, *generality, impact on artefact environment and user, internal consistency*, or *external consistency*. The following methods typically apply to this activity:

- Case study
- Field experiment
- Survey
- Expert interview
- Focus group

The patterns pertinent to the Eval4 activity can be termed *case study*, *field experiment*, *survey*, or *applicability check*.

The results of this evaluation activity might stimulate further iterations through the DSR process depicted in Fig. 3. Subsequent iterations may refer to the same or an adapted problem statement. It is also possible that while the problem might not change the purpose and thus the applied evaluation criteria of subsequent evaluations (Eval1, Eval2, Eval3, Eval4) may change. This could be required if a DSR project should be adapted to stakeholder needs that have not been addressed within previous iterations through a particular DSR process.

Below, selected patterns will be presented: the “*assertion*” pattern, the “*demonstration*” pattern, and the “*prototyping*” pattern. These patterns have been selectedhere for two reasons: (1) they support the justification of artefact designs and trigger the revision of design decisions early in the process, and (2) they very frequently occur within DSR literature, however, their appropriateness within a given design context has been reflected only very rarely.

Evaluation patterns pertinent to the Eval1 and Eval4 activities respectively have been discussed extensively in related work on research methods. What has not been provided so far is that the applicable patterns have been positioned and contextualized within a DSR process as depicted in Fig 3. In this regard our paper provides a contribution as it locates applicable evaluation patterns within a DSR process. The pattern descriptions discussed below are structured according to their *intent*, the *context and applicability*, *description*, *implications*, and *examples* [cf. 11].

3.2 The "Assertion" Pattern

Intent

Make an *informed argument* [cf. 2] about why the artefact design is superior and will work in a given situation.

Context and Applicability

The researcher has formulated a problem statement or specified an artefact design according to some previously stated design objectives. The researcher wants to show that his approach or his design is superior compared to previous approaches or artefact designs. The researcher has prepared a rudimentary test case but did not justify why his data might be "representative". The researcher might also have a theoretical model that informed the artefact design and thus expects the artefact design to work as predicted or prescribed by the theory.

Description

1. Specify the problem or artefact design (formal language, diagram, text).
2. Describe an instance of a business problem.
3. Provide a *test case* or *theory*.
4. Demonstrate how the artefact is expected to work given the specified constraints and data set.

Consequences

The researcher might provide a sound motivation of why an artefact design is expected to solve a particular business problem. However, providing an informed argument is considered being a "weak example favouring the proposed technology over alternatives" [12, p. 26]. Assertions are potentially biased since the goal is not to understand the difference between alternative designs but to demonstrate that an artefact design is superior [12]. Assertions are the weakest form of validating an artefact and should be avoided except for motivating the design of an artefact.

Examples

1. A study reported in [12] found that among the papers that have been analysed in the computer science discipline predominantly make use of assertions to validate their solutions. A representative generic example of an assertion used in computer science is provided in [12, p. 30]: "Use the tool to test a simple 100-line program to show that it can find all errors."

3.3 The "Demonstration – Ex ante" Pattern

Intent
Demonstrate that an artefact design embodies the solution to the identified business problem and works in the context of an artificial setting.

Context and Applicability
The researcher has specified an artefact design according to some previously stated design objectives. The problem statement as well as the artefact design do not allow for formally proving the correctness of the artefact design. No prototype has been constructed so far. The researcher might want to demonstrate that the design properties of the artefact allow for solving the business problem or even the class of problems of which the concrete business problem represents an instance.

Description

1. Specify the artefact design (formal language, diagram, text).
2. Describe one or more instances of a business problem.
3. Construct a *test case* or *analytical example* by providing relevant input data and constraints.
4. Provide justification for the constraints and data values.
5. Demonstrate how the artefact is expected to work given the specified constraints and data set.

Consequences
The researcher may show that the artefact design already embodies a solution to the identified business problem. It is also expected that exercising analytical examples may trigger design revisions early within the design process as the researcher may identify inadequacies [cf. 11]. The use of standardised test cases or test cases that have already been applied by others may strengthen the significance of the evaluation results.

Examples

1. CHEN [13] (taken from [11]) provided a description of his entity-relationship model and the associated diagrammatic technique and demonstrated its use by means of an example.

2. VOM BROCKE ET AL. [14] synthesised accounting constructs and business process management constructs into a process-oriented accounting model. They demonstrated how their accounting model could serve to provide information on value generation in business processes by means of an example that has already been presented in other publications by other authors.

3.4 The "Prototyping" Pattern

Intent

Implement an artefact design as a generic solution to demonstrate the artefact's suitability [5].

Context and Applicability

The researcher has specified an artefact design according to some previously stated design objectives. The artefact design is operationalizable and the researcher could provide an implementation of the solution by means of a prototype (individual software, new module or service within a given system). The researcher might want to demonstrate that the artefact works in practice and solves the identified business problem, i.e. it is feasible. The researcher might want to see how the artefact interacts with organizational elements, i.e. "real tasks", "real users", or "real systems".

Description

1. Specify the artefact design (formal language, diagram, text).
2. Provide an implementation according to the artefact design specification. Construct a *test case* or *analytical example* by providing relevant input data and constraints; or select a "real task" in an organization.
3. Select "real users" if prototype is applied within an organizational context.
4. Use the prototype.
5. Assess whether the tasks could be solved as intended by using the prototype.

Consequences

The researcher could show that artefact design and its corresponding prototype are suitable to solve the particular business problem. The researcher could also identify unintended effects of an artefact as they emerge in the interaction with other organizational elements [cf. 7]. In fact, prototyping is regarded as an adequate evaluation method for DSR artefacts [5]. A design researcher could already apply naturalistic evaluations in order to capture the organizational context and infer on the artefacts usefulness before it is actually used within an organization.

Examples

1. LEE ET AL. [15] defined a method for generating and managing business process design alternatives and they also provided a software prototype to support the use of this method. The prototyping considered a "real task" and "real users".

2. SONNENBERG ET AL. [16] specified a domain specific language (DSL) for creating and documenting business models along with a prototypical modelling tool. Their prototyping considered a “real task”. The purpose was to show that their DSL was expressive and receptive of modelling problems that could theretofore not be solved or could have been solved by means of very complex solutions if not modelled with the presented DSL.

4 Conclusion

Current design science research literature provides little guidance on how to structure artefact evaluation strategies. This paper addresses this shortcoming by presentingDSR evaluation patterns. These patterns have been synthesised from the DSR literature and reflect the structure of DSR processes, DSR evaluation criteria, as well as existing DSR evaluation frameworks. The paper positions the identified evaluation patterns along a general DSR process and distinguishes both ex ante as well as ex post evaluations of DSR artefacts.

While the formulation and presentation of evaluation patterns aimed at supporting design researchers, the presented set of patterns is by no means expected to be complete. Further research is required to specify additional patterns as well as to explicate possible interdependencies between evaluation patterns. This could also contribute to define higher order composite patterns that could be used to even distinguish between different types of DSR research processes and generic evaluation criteria pertinent to such generic research process types.

References

1. March, S.T., Smith, G.: Design and Natural Science Research on Information Technology. Decision Support Systems, 15 (4), 251--266 (1995)
2. Hevner, A.R., March, S.T., Park, J., Ram, S.: Design Science in Information Systems. MIS Quarterly, 28 (1), 75--105 (2004)
3. Pries-Heje, J., Baskerville, R., Venable, J.: Strategies for Design Research Evaluation. In: 16th European Conference on Information Systems (ECIS 2008), Galway, Ireland (2008)
4. Cleven, A., Gubler, P., Hüner, K.M.: Design Alternatives for the Evaluation of Design Science Research Artifacts. In: 4th International Conference on Design Science Research in Information Systems and Technology, Philadelphia, PA (2009)
5. March, S.T., Stortey, V.C.: Design Science in the Information Systems Discipline: An Introduction to the Special Issue one Design Science Reseaerch. MIS Quarterly, 32 (4), 725 --730 (2008)
6. Peffers, K., Tuunanen, T., Rothenberger, M.A., Chatterjee, S.: A Design Science Research Methodology for Information Systems Research. Journal of Management Information Systems, 24 (3), 45--77 (2007)
7. Sein, M.K., Henfridsson, O., Purao, S., Rossi, M., Lindgren, R.: Action Design Research. MIS Quarterly, 35 (1), 37--56 (2011)
8. Aier, S., Fischer, C.: Criteria for Progress for Information Systems Design Theories. Information Systems and E-Business Management, 9 (1), 133--172 (2011)
9. Rosemann, M. Vessey, I.: Toward Improving the Relevance of Information Systems Research to Practice: The Role of Applicability Checks. MIS Quarterly, 32 (1), 1--22 (2008)

10. Sun, Y., Kantor, P.B.: Cross-Evaluation: A new model for information system evaluation. Journal of the American Society for Information Science and Technology, 57 (5), 614--628 (2006)
11. Vaishnavi, V.K., Kuechler, W.: Improving and Innovating Information & Communication Technology: Design Science Research Methods and Patterns, Taylor Francis (2008)
12. Zelkovitz, M.V., Wallace, D.R.: Experimental Models for Validating Technology. IEEE Computer, 31 (5), 21--31 (1998)
13. Chen, P.P.: The Entity-Relationship Model. Towards a unified view of data. ACM Transactions on Database Systems, 1 (1), 9--36 (1976)
14. vom Brocke, J., Sonnenberg, C., Baumoel, U.: Linking Accounting and Process-aware Information Systems – Towards a Generalized Information Model For Process-oriented Accounting. 19th European Conference on Information Systems (ECIS 2011), Helsinki, Finland (2011)
15. Lee, J., Wyner, G.M., Pentland, B.T.: Process Grammar as a Tool for Business Process Design. MIS Quarterly, 23 (4), 757--778 (2008)
16. Sonnenberg, C., Huemer, C., Hofreiter, B., Mayrhofer, C., Braccini, A.: The REA – DSL: A Domain Specific Modeling Language for Business Models. 23rd International Conference on Advanced Information Systems Engineering, London, United Kingdom, 252--266 (2011)