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A Conceptual Framework to Construct an Artefact for Meta-Abstract Design Knowledge in Design Science Research

Łukasz Ostrowski, Markus Helfert, Shuyan Xie

School of Computing, Dublin City University, Glasnevin, Dublin 9, Ireland
{Lostrowski, Markus.Helfert, Shuyan Xie}@computing.dcu.ie

Abstract

Based on reviewing foremost literature, the paper presents a design science research methodology with strategies for design science evaluation, and multi-grounded theory as an approach to design an artefact. For producing an artefact a problem of applying design science, which will detail some design science activities, is presented along with the solution in form of a conceptual framework that allows using other research disciplines. The framework aims to fill out the lack of details in design science methodology for developing abstract design knowledge.

1. Introduction

Over the last years, design science research has received increased attention in computing and information System (IS) research. Generally, research, as a process "is the application of scientific method to the complex task of discovering answers (solutions) to questions (problems)" [1].We can differentiate between the study of natural systems, such as physics, biology, economics and sociology [2] and the creation of artificial ones, such as medicine and engineering [2,3]. The core mission of the former is to develop valid knowledge to understand the natural or social world, or to describe, explain and possibly predict. The centre of the latter is to develop knowledge that can be used by professionals in the field in question to design solutions to their field problems. Understanding the nature and causes of problems can be a great help in designing solutions, and is the focus of design science [4]. However, design science does not limit itself to the understanding, but also aims to develop knowledge on the advantages and disadvantages of alternative solutions [4]. The main requirements are rigour and relevance [5,6,7].

Although there have been numerous contributions related to design science, there are still some fundamental challenges related with this research process. In this paper we aim to show some of these challenges, in particular related to detailing design activity in order to produce abstract design knowledge.

In this paper we discuss current work on design science methodologies. We observed that numbers of proposed methodologies for design science increased in recent years. These methodologies propose various models. These models contain steps, which invoke certain activities. We concentrate on literature review, modelling, and engagement scholarship as the activities that play crucial role in artefact design. However, these methodologies do not provide much detail on implementation of those activities. We believed that knowing these activities will allow us to construct a framework. The framework will guide researchers throughout the artefact design. Mostly we concentrate on activities that occur across various design science methodologies in a step in which an actual artefact is being created/produced/developed.

Our conceptual framework to these challenges is based on reviewing related literature. The remainder of the paper is organized as follows. First, we review the general process of design science research methodology. Next, we distinguish between abstract and situational knowledge in terms of designing artefacts as an output of the method. Then, we discuss the multi-grounded theory along with its application in evaluation strategies for design science research. Finally we present a conceptual framework that is used to develop an artefact that will detail design science methodology.

2. Design science research methodology

A number of researchers, both in and outside of the Information Systems (IS) discipline, have sought to provide some guidance to define design science research [6]. Their work in engineering [8,9,10,11], computer science [12,13], and IS [14,15,12,16,17,18,19] have aimed to collect and distribute the appropriate reference literature [20]; characterize its purposes, differentiate it from theory building and testing research and from other research paradigms.

They enhanced its essential elements; and claim its legitimacy. However, despite several guidelines the

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literature has not explicitly focused on the design & development step of design science research [21]. Offerman states that this step is a creative engineering process, and not much guidance is provided in IS literature [22].

Some researchers in IS and other disciplines have contributed ideas for process elements [8,13,9,18,17,12]. These papers include some component in the initial stages of research to define a research problem. Nunamaker et al. [1] and Walls et al. [18] emphasized theoretical bases, whereas engineering researchers [8,9] focused more on applied problems. Takeda et al. [13] suggested the need for problem enumeration, whereas Rossi and Sein [17] advocated need identification. Hevner et al. [6] asserted that design science research should address important and relevant problems. Based on those seven representative papers which stated or suggested process elements, the components of the Design Science Research Methodology (DSRM) were synthesized [21]. The result of the synthesis was a process model consisting of six activities in a nominal sequence. We describe them here and graphically in Figure 1.

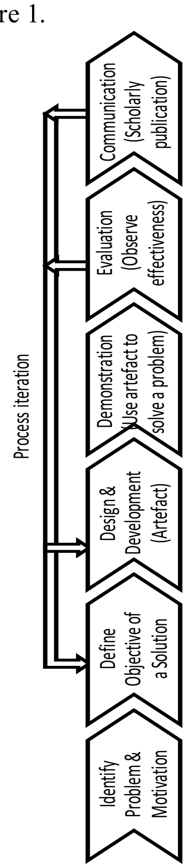

Figure 1. DSRM process Model [17].

Problem identification and motivation defines the specific research problem and justifies the value of a solution [21]. *Define the objectives for a solution* refers to the objectives of a solution from the problem definition and knowledge of what is possible and feasible [21]. *Design and development* creates artefacts. Such artefacts are potentially constructs, models, methods, or instantiations [6] or "new properties of technical, social, and/or informational resources" [3]. Conceptually, a design research artefact can be any designed object in which a research contribution is embedded in the design [21]. *Demonstration* refers to the use of the artefact to solve one or more instances of the problem. Resources required for the demonstration include effective knowledge of how to use the artefact to solve the problem [21]. *Evaluation* observes and measures how well the artefact supports a solution to the problem. This activity involves comparing the objectives of a solution to actual observed results from use of the artefact in the demonstration [21]. *Communicate* refers to the problem and its importance, the artefact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences such as practicing professionals. This could be in form of a PhD thesis, journal or conference article [22]. In scholarly research publications, researchers might use the structure of this process to structure the paper, just as the nominal structure of an empirical research process (problem definition, literature review, hypothesis development, data collection, analysis, results, discussion, and conclusion) is a common structure for empirical research papers [21].

3. Abstract and situational design

Design research produces different artefacts with Design and Development activities of a DSRM process model [21]. The outcome of design science is an artefact, which can be in form of a construct, model, method, and an instantiation [16,6]. Some researchers understand artefacts as "things", i.e. entities that have some separate existence [10]. Constructs are defined as "concepts" and "conceptualizations" [16] and "vocabulary and symbols" [6]. These constructs are abstracted concepts aimed for theorizing and trans-situational use. "Conceptualizations are extremely important in both natural and design science. They define the terms used when describing and thinking about tasks" [16]. Models are not conceived as abstract entities in the same way as constructs. "Models use constructs to represent a real world situation – the design problem and its solution space…" [6] "Models aid problem and solution understanding and frequently represent the connection between problem and solution components enabling exploration of the effects of design decisions and changes in the real world." [6]. A method is defined as "a set of steps (an algorithm or guideline) to perform a task" [16]. An instantiation is a prototype or a specific working system or some kind of tool [10].

Design research uses and produces design knowledge, which can be either in a form of abstract or situational design knowledge [10]. Following this differentiation, Goldkuhl and Lind [23] divided design research into two activity layers: 1) design practice that produces situational design knowledge and concrete artefacts and 2) meta-design that produces abstract design knowledge. The reasoning can be explained in the following example. Hevner's [6] models are conceived as situational. This is, however, a too restricted view on models [23]. This can be illustrated by the Action Workflow Loop [24]. This is a generic action pattern consisting of four action phases. Based on this generic model (functioning as a template) it is possible, in situational design to create situational models (loop models) consisting of these four action phases. We should therefore distinguish between generic models (as abstract design knowledge) and situational models (as situational design knowledge) [23].

This paper focuses on abstract design knowledge produced in the meta-design step. It can be viewed as 1) a preparatory activity before situational design is started and 2) a continual activity partially integrated with the design practice 3) a concluding theoretical activity summarizing, evaluating and abstracting results directed for target groups outside the studied design and use practices [23]. As a result we receive four different outcomes for each activity layer (see Table 1).

Table 1. Different outcomes differentiated into abstract vs. situational [8].

Activity/ Outcome	**meta design: Abstract design knowledge**	**design practice: Situational design knowledge**
Constructs	abstract concepts	situational concepts (may be applied and adapted from abstract concepts)
Models	generic models	situational models
Methods	guidelines for design practice	parts of a situational system or process
Instantiation	(systems abstractions with key properties)	Instantiations IT systems (prototype or working system)

4. Artificial and situational evaluation

As discussed above, abstract and situational design knowledge can be treated as two individual outcomes of design science as stated in section 3. Thus, it seems reasonable to consider two different evaluation methods for each of them - ex post and ex ante. Evaluation has been a topic both in general IS research and in design science research. In the general IS literature, evaluation is generally regarded from one of two perspectives [24]. In the *ex-ante* perspective, candidate systems or technologies are evaluated before they are chosen and acquired or implemented. In the *ex post* perspective, a chosen system or technology is evaluated after it is acquired or implemented [24].

Venable [19] classified design science research evaluation approaches into two primary forms: artificial and naturalistic evaluation. Artificial evaluation evaluates a solution technology in a contrived and non-realistic way. Naturalistic evaluation explores the performance of a solution technology its real environment (i.e. within the organisation). Naturalistic evaluation methods offer the possibility to evaluate the real artefact in use by real users solving real problems [25], while artificial evaluation methods offer the possibility to control potential confusing variables more carefully and prove or disprove design hypotheses, design theories, and the utility of design artefacts. Having taken into account those two dimensions, Pries-Heje et al. [26] introduced an evaluation framework. We applied the framework to the DSRM process model in Figure 2. We split the Design and Development activity into meta-design and design practice. Since different artefacts are achieved from each activity, a different evaluation strategy applies.

Artificial evaluation is selected after the meta-design activity because of its capability to test design hypotheses. [18]. Critical techniques may be used, but these generally supplement the main goal of proving or disproving the design theory and/or the utility of the design science artefact. Artificial evaluation includes laboratory experiments, field experiments, simulations, criteria-based analysis, theoretical arguments, and mathematical proofs [26]. Artificial evaluation is then unreal in some way or ways according to the three realities [25], such as unreal users, unreal systems, and especially unreal problems (not held by the users and/or not real tasks, etc.). The naturalistic evaluation after the design practice outcome was chosen due to the capability of performing evaluation in a real environment (real people, real systems (artefacts), and real settings [25], naturalistic evaluation embraces all of the complexities of human practice in real organisations. Naturalistic evaluation methods include case studies, field studies, surveys, ethnography, phenomenology, hermeneutic methods, and action research. To the extent that naturalistic evaluation is affected by confusing variables or misinterpretation, evaluation results may not be precise or even truthful about an artefact's utility or efficacy in real use [26]

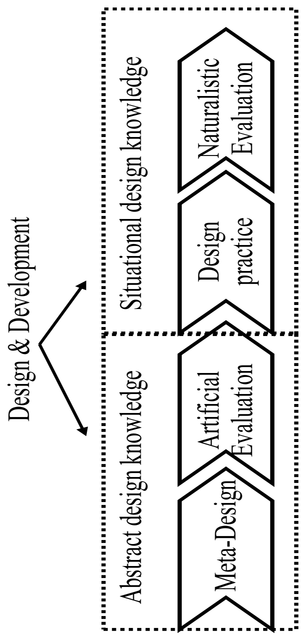

Figure 2. Decomposition of Design & Development step from Figure 1.

5. Multi grounded knowledge

Design research consists of an empirical part (a design practice) and a theoretical part (meta-design). The two parts exchange knowledge. Meta-design produces abstract design knowledge and the design practice produces situational design knowledge and other situational results (instantiations/IT systems). These knowledge types and results are exchanged between the two parts of design research. The knowledge exchanges are also parts in grounding processes. Situational design knowledge is used for empirical grounding of abstract design knowledge and abstract design knowledge is used for theoretical grounding of situational results [10]. The justification of design knowledge means to investigate and present warrants for such knowledge. Three types of knowledge sources and warrants give rise to three grounding processes: Empirical grounding, theoretical grounding and internal grounding (Figure 3). Empirical grounding comprises grounding through application of design knowledge and observations of its utilisation and effects. Theoretical grounding includes also grounding in concepts and values. Internal grounding involves control of internal cohesion and consistency. All three grounding processes should be applied [23].

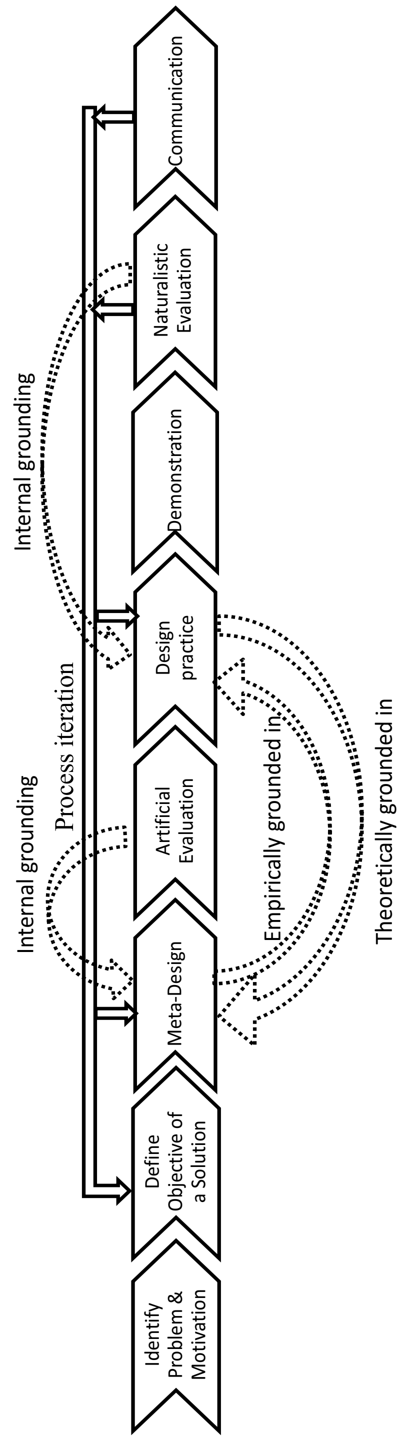

Figure 3. Application of Multi-grounding [8] on DSRM process model [17] with evaluation on artificial and situational knowledge.

These three types of knowledge sources are used both for generation and justification of design knowledge. A design theory may be partially derived from and inspired by other theories and through empirical observations.

6. The conceptual framework for abstract design knowledge

Drawing upon the above literature and our discussion, Figure 3 presents our combined findings on how to approach design science. However, when it comes down to meta-design for the abstract-design knowledge outcomes, not sufficient guidelines can be found. Offerman [22] claimed that not much guidelines is provided in IS literature on this step, and proposed that focus should be put on relevant scientific publications (i.e. literature review) regarding the desired artefact. In his proposed design science research process, an expert survey and case study research activities are only involved in the evaluation step. We propose that for meta-design step, these activities along with expert's knowledge should be involved in designing artefacts, and treated as a separate entity (i.e. engagement scholarship) [27]. Since a literature review and engagement scholarship provide information regarding the desired artefact, a way of presenting relevant findings in a rigour structure seems reasonable. Thus, we propose, that modelling techniques should be accompanied to the mentioned sources of information. As a result we can distinguish three sub-steps involved in the meta-design step: literature review, modelling and engagement scholarship (see Figure 4).

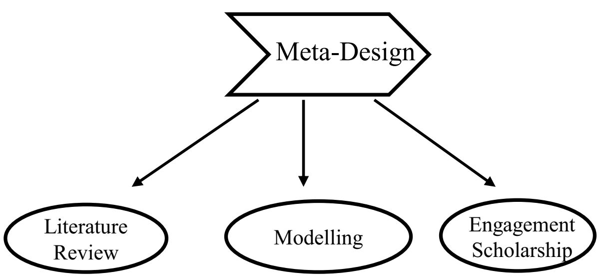

Figure 4. Activities that produce an abstract design knowledge artefact.

Literature to date does not provide much detail on how to approach these three sub-steps in design science. Therefore, we propose the conceptual framework to develop an artefact that will detail the meta-design activity that produces abstract design knowledge. This is one of the challenges in the design science research process. One view is that, these three sub-steps might be seen as an individual artefact, so we could just reach for design science, because it aims to develop knowledge that can be used by professionals in the field in question to design solutions to their field problems [4]. However, this approach leads to an occurrence of a recursion effect, which will be shown in an example.

First, we will present the conceptual framework and its outcome, and then the example which underlines the fact that these three sub-steps can only be partly produced using design science methodology. It demonstrates how our conceptual framework deals with this issue. The application of the framework should result in detailing the meta-design step by providing guideline on how to approach literature review, engagement scholarship and modelling in design science methodology.

6.1 Reasoning to the conceptual framework for abstract design knowledge

In previous section we discussed that the three sub-steps (literature, review, engagement scholarship, modelling) in meta-design work together to produce abstract design knowledge. Figure 5 illustrates our assumption of their dependence, and claim that these three sub-steps cannot be approach individually. In other words we need to consider the three activities as one artefact. Our reasoning is further explained in the example. The arrows between sub-steps indicate that information gathered from one source should be confronted with the other. In the sense, how the theory from literature is, actually, used in practice, and how the best practice reflects theory. The gathered information is presented using relevant modelling techniques.

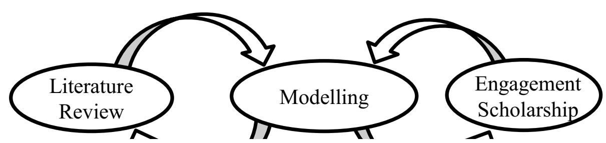

Figure 5. Relations between activities that produce an abstract design knowledge artefact.

The following example shows that we cannot use design science to produce the artefact that contains the three sub-steps. Therefore we refer to the definition of IS which is the applied research discipline [21]. In the sense, that we frequently apply theory from other disciplines, such as economics, computer science, and the social sciences, to solve problems at the intersection of information technology and organizations [21]. Thus, the literature review activity and two others can be produced by comparing multiple plausible models of reality, which are essential for developing reliable scientific knowledge [28]. However, these models would still need redesigning to fit the purpose of the output in meta-design step. This is why we need the conceptual framework. The idea is to apply theories of disciplines of the three sub-steps to the outcome level of the artefact of interest, and then combine. For example, we intuitively reach for plausible constructs in domains of literature review, engagement scholarship, and modelling. Then we come up with a common construct for each domain, and combine, so that in a result we get a general construct on how to conduct these three sub-steps all together (Figure 6) in meta-design step. Upon having the construct we go deeper into these domains to accordingly get model, method, and instantiation. Following this approach we will produce an artefact in the form that provides substantial guidelines on how to conduct literature review, engagement scholarship, and modelling in meta-design step for the purpose of an abstract design knowledge artefact. In other words, by using this framework we will detail the meta-design step in design science.

The word *evaluation* also appears in our framework. To keep it clear, the artificial evaluation was a part of the abstract design knowledge in our earlier discussion (Figure 2 and 3). The difference between it and the evaluation, used in the conceptual framework (Figure 6), is that the evaluation is used in the process of producing the artefact of three sub-steps for meta-design as oppose to evaluation (e.g. artificial evaluation) of an artefact, which is created following design science research. Our new-created meta-design artefact will be the guideline for the three sub-steps showed in Figure 5. We believe that the embedded evaluation will cause lower incorrectness of the guideline upon applying artificial evaluation.

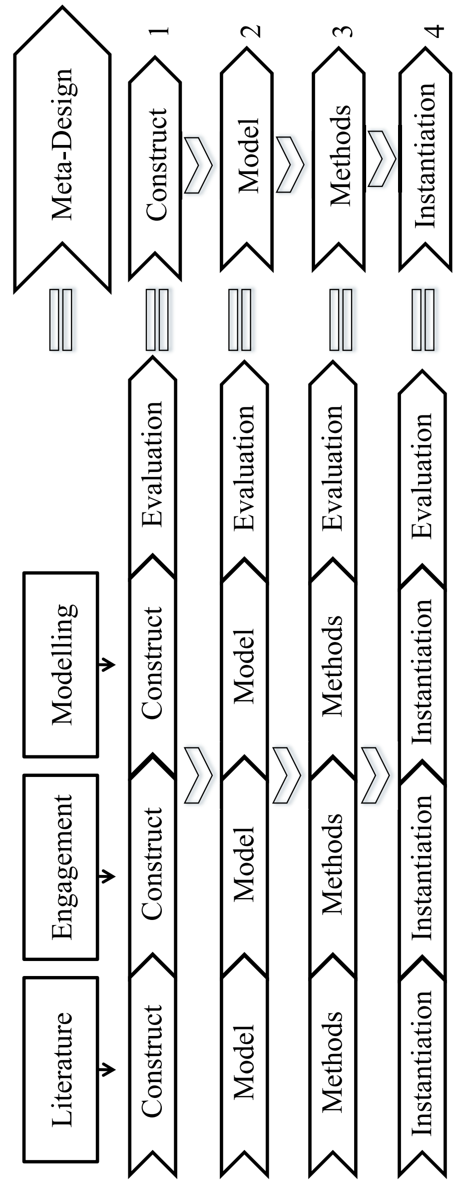

Figure 6. A conceptual framework that builds the artefact for meta-design step.

6.2 The example – design science to produce sub-steps for the meta-design step

In this example, we use design science methodology, discussed in previous sections, and presented in Figure 3, to show that sub-steps of meta-design cannot be produced with that methodology and these sub-steps should not be treated individually.

Accordingly the first step is to *identify a problem & motivation*. In our case, we found that a systematic literature review would increase a process of retrieving relevant information about a domain under consideration. We also noticed that IS researchers do not provide enough details on the literature review activity in design science methodology. We are motivated to specify it, and distribute to others. Next step in design science is to *define objective of a solution*. We aim to provide a systematic guideline on literature review that would help other researchers thoroughly conduct this activity. The solution will be in form of rules and steps that need to be fulfilled to reach desired outcome. The following step is *meta-design* in which we produce the abstract design knowledge. Four possible outcomes are available (see Table1). We understand that the instantiation for meta-design should base on the method, which were embedded in the model whose beginning can be found in the construct. In the other words, the instantiation is a cumulative outcome at some stage (see Figure 5 for the linear approach). Thus, to achieve an instantiation of the literature review artefact, we need to produce a construct first. According to our discussion summarized in Figure 3, we use sub-steps such as engagement scholarship, modelling and literature review to produce the construct for desired literature review artefact. Consequently, we reach first for the literature review sub-step to gain information needed to develop the construct. This sub-step should tell us what actions we are required to take; however, since we are designing the literature review artefact, we do not know yet how this activity should look like. Hence, we could follow the line of thought and ask the question on how to conduct the literature review activity. If we reached for design science again to design the artefact of literature review, we would end up at the same step. Thus, this reasoning leads us to the recursion effect. By way of explanation we need to know the literature review in order to design the literature review. As a result the design science methodology for the literature review artefact does not seem appropriate. Otherwise, we would raise the same question over and over again once the sub-step in meta-design is reached. We get the same conclusions upon using design science methodology for the rest two sub-steps: engagement, and modelling if we aim to produce modelling artefact for example. This recursion effect is caused by two factors, first is that, as we stated in previous section, these three sub-steps are related to each other (Figure 4). We need to model results upon conducting a literature review and engagement scholarship. Therefore these steps should not be considered individually. The second is that you cannot use methodology to produce an artefact, which appears as a method in that methodology. In order to overcome the recursion effect we came up with a solution that requires designing these sub-steps in parallel. The solution to that issue is our conceptual framework and the artefact, developed thanks to it, will detail meta-design step in design science methodology.

Conclusions

In this paper we presented how the design science research methodology [21] corresponds with the strategies for design science research evaluation [26], and the multi-grounded design research process [23] (Figure 3). We presented that design activity in DSRM can be split into abstract and situational design knowledge. We concentrated on developing an artefact that will serve as a guideline to produce abstract design knowledge. In order to develop the guideline we discussed that design science research could not be applied. We introduced our conceptual framework to produce the guideline, which will be in a form of instantiation. The conceptual framework included literature review, engagement scholarship, evaluation, and modelling. These activities are used and combined in parallel to achieve the guideline, which will detail the meta-design activities in design science, provide researchers with a systematic approach while producing meta-design artefact. The guideline of the meta-design step will contain literature review, modelling, and engagement scholarship. The outcome of the conceptual framework will be applied and validated via case studies in our future research.

References

1. Nunamaker, J. F., Chen, M., Purdin, T.D.M.: Systems Development in Information Systems Research. Journal of Management IS 7(3), 89-106 (1991)
2. Van Aken, J.: Management Research Based on the Paradigm of the Design Sciences: the Quest for Tested and Grounded Technological Rules. Journal of Management Studies 41(2), 219-246 (2004)
3. Simon, H.: The Sciences of the Artificial 3rd edn. MIT Press, Cambridge (1996)
4. Van Aken, J. E.: Management Research as a Design Science: Articulating the Research Products of Mode 2 Knowledge Production in Management. British Journal of Management 16(1), 19-36 (2005)
5. Benbasat, I., Zmud, R. W.: Empirical Research in Information Systems- The Practice of Relevance. MIS Quarterly 23(1), 3-36 (1999)
6. Hevner, A. R., March, S. T., Park, J., Ram, S.: Design Science in Information Systems Research. MIS Quarterly 28, 75-106 (2004)
7. 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)

8. Archer, L. B.: Systematic Method for Designers. In : Developments in Design Methodology, London, pp.57-82 (1984)
9. Eekels, J., Roozenburg, N. F. M.: A Methodological Comparison of the Structures of Scientific Research and Engineering Design-Their Similarities and Differences. Design Studies 12(4), 197-203 (1991)
10. Goldkuhl, G.: Design Theories in Information Systems – A Need for Multi-Grounding. Journal of Information Technology and Application 6(2), 59-72 (2004)
11. Reich, Y.: The Study of Design Methodology. Journal of Mechanical Design 117(2), 211-214 (1994)
12. Preston, M., Mehandjiev, N.: A Framework for Classifying Intelligent Design Theories. In Mehandjiev, N., Brereton, B., eds. : The 2004 ACM Workshop on Interdisciplinary Software Engineering Research, New York, pp.49-54 (2004)
13. Takeda, H., Veerkamp, P., Tomiyama, T., Yoshikawam, H.: Modelling Design Processes. AI Magazine 11(4), 37-48 (1990)
14. Adams, L., Courtney, J.: Achieving Relevance in IS Research via the DAGS Framework. In : 37th Annual Hawaii International Conference on System Sciences (2004)
15. Cole, R., Purao, S., Rossi, M., Sein, M. K.: Being proactive- Where Action Research Meets Design Research. In : 26th International Conference on Information Systems, Atlanta, p.325–336 (2005)
16. March, S., Smith, G.: Design and Natural Science Research on Information Technology. Decision Support Systems 15(4), 251-266 (1995)
17. Rossi, M., Sein, M. K.: Design Research Workshop: A Proactive Research Approach. In : 26th Information Systems Research Seminar in Scandinavia, Haikko, pp.9-12 (2003)
18. Walls, J., Widmeyer, G., El Sawy, O.: Building an Information System Design Theory for Vigilant EIS. Information Systems Research 3(1), 36-59 (1992)
19. Venable, J.: A Framework for Design Science Research Activities. In : The 2006 Information Resource Management Association Conference, Washington DC (2006)
20. Vaishnavi, V., Kuechler, B.: Design Research in Information Systems. Association for Information Systems (2005)
21. Peffers, K., Tuunanen, T., Rothenberger, M.: A Design Science Research Methodology. Journal of Management Information Systems 24(3), 45-77 (2007)
22. Offermann, P., Levina, O., M., S., Bub, U.: Outline of a Design Science Research Process. In : Design Science Research in Information Systems and Technology, Malvern (2009)
23. Goldkuhl, G., Lind, M.: A Multi-Grounded Design Research Process. In Winter, R., Shao, L., Aier, S., eds. : Global perspectives on design science research DESRIST 2010, Berlin, vol. 6105, pp.45-60 (2010)
24. Medina-Mora, R., Winograd, T., Flores, R., Flores, F.: The Action Workflow Approach to Workflow Management Technology. In Turner, J., Kraut, R., eds. : Computer-Supported Cooperative Work, New York (1992)
25. Klecun, E., Cornford, T.: A Critical Approach to Evaluation. European Journal of IS 14(3), 229-243 (2005)
26. Sun, Y., Kantor, P.: Cross-Evaluation: A New Model for Information System Evaluation. Journal of the American Society for Information Science and Technology 57(5), 614-62 (2006)
27. Pries-Heje, J., Baskerville, R., Venable, J.: Strategies for Design Science Research Evaluation. In : 16th European Conference on Information Systems, pp.255-266 (2008)
28. Van de Ven, A.: Engaged Scholarship: A Guide for Organizational and Social Research. New York: Oxford University Press, Oxford (2007)
29. Azevedo, J.: Mapping Reality: An Evolutionary Realist Methodology for the Natural and Social Sciences., Albany (1997)
30. Van de Van, A.: Engaged Scholarship: A Guide for Organizational and Social Research. New York: Oxford University Press, Oxford (2007)
31. Azevedo, J.: Mapping Reality- An Evolutionary Realist Methodology for the Natural and Social Sciences. NY: State University of New York Press, Albany (1997)
32. Alturki, A., G.G., G., W., B.: A Design Science Research Roadmap. In Jain, H., Sinha, A. P., Vitharana, P., eds. : DESRIST 2011, Heidelberg, vol. LNCS 6629, pp.107-123 (2011)