Logic for Design Science Research Theory Accumulation

Jan Holmström
Industrial Engineering and Management, Aalto University School of Science, Espoo, Finland
jan.holmstrom@aalto.fi

Tuure Tuunanen
Computer Science and Information Systems, University of Jyväskylä, Jyväskylä, Finland
tuure@tuunanen.fi

Jouni Kauremaa
Industrial Engineering and Management, Aalto University School of Science, Espoo, Finland
jouni.kauremaa@iki.fi

Abstract

The paper introduces a structured logic for iterative and incremental accumulation of a design theory during a research project and across research programs. The logic is proposed to help researchers understand the links between parallel search spaces related to a particular design and linking to theoretical knowledge bases produced by previous search processes. The proposition rests on the notion that representing the structure and logic of design science research (DSR) theory using CIMO enables the elements of the knowledge base to be more easily evaluated, combined, and transferred between related search spaces. We view DSR theory development as an iterative and incremental social process and propose a structured logic as a means to better understand, but also guide, DSR theory development over time.

1. Introduction

Theoretical knowledge evolves through combinations [1]; and, at any one time, there can be large numbers of potential new combinations waiting to happen. Feldman, Csikszentmihalyi, & Gardner [2] posit that new combinations are a result of individual interaction with different symbolic domains and fields of expertise. Different symbolic languages, developed in parallel search spaces, restrict and slow down combinations; successful combinations are an outcome of individuals' ability to overcome the bounds of rationality [3].

Simon and Klahr's [4] search space model explicates the interaction between individual, field and multiple symbolic domains as a process of a search in different search spaces. For a typical scientific field, the suggested search spaces are hypothesis, representation, experiment, and paradigm.

Furthermore, Simon [3] notes that search processes are separated and connected at the same time. First, they are separated because the different actors conducting the searches are boundedly rational so that different individuals or groups may, in parallel, develop partly contradictory designs or even opposing paradigms [5]. The search is also connected, because the theoretical knowledge that has been accumulated by such searches can be combined later to produce something exceeding the sum of parts [1], creating a structure that Simon views as "almost decomposable hierarchy." [3]

Hence, in order to facilitate the accumulation of knowledge across search spaces, there is a need for a foundation that places compatible search activities and nodes in a network [1, 6]. A logic structure for accumulation of the theoretical knowledge base across a network of search spaces is proposed as the basis for *accumulation of DSR theory*.

The problem that we address is how to transfer and combine knowledge from parallel search spaces that are relevant to design science research. The mode of design advocated by design science research [7, 8] consists of build cycles followed by evaluation. We argue that a different mode is needed for accumulation of design theory. For accumulation to occur, a number of problems related to DSR theory development must be addressed, namely: 1) transfer, 2) combination, and 3) the evaluation of different types of knowledge. The objective of this paper is to propose a structure supporting DSR theory accumulation over time.

In the following, we first introduce a specific type of design logic to the information systems (IS) context. Then, we develop an argument for structured DSR theory accumulation. Finally, we present the logic as a means for facilitating accumulation of design

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theory in IS research, including two exemplars that illustrate potential use.

2. Logic for accumulation of theoretical knowledge

Practice-oriented, or applied, management research has, by different academics, been alternatively termed as design science in management [9], evidence-based management [10], and innovation action research [11], just to mention a few. This approach to management research is similar to design science research [7] and action design [8] in the information systems field. The similarity is in the emphasis on solving practical problems through artifacts, such as information systems and management processes.

However, there is a difference in this emphasis that can be described as a search in distinct, but interrelated, spaces. The primary interest in management research is the available uses of the designs and the impact of their use in addressing management problems. The intended outcomes of the research efforts are dependent on the emphasis: field-tested means-ends propositions [3], technological rules [9], construction principles and design rules [12], or design theory [13].

Accumulation of DSR knowledge requires a means for how prior DSR theory and empirical research can contribute to solution design and practice. Introducing a structure to facilitate such accumulation of theoretical knowledge is a way to make prior design, theory, and empirical evidence more easily available for transfer and combination, as well as evaluation.

As the means for structuring the theoretical knowledge base, we propose a logic that takes the notion of separate search spaces as a starting point. The concept of search spaces was developed in Klahr and Simon's [4] study of discovery in science: discovery involves separate search spaces with distinct but interdependent knowledge interests and actors. In design science research literature, design is already described as a "search process"; for example, in guideline six of Hevner et al. [7]. Many authors, such as [14, 15], describe how DSR theory is initially proposed based on an artifact. Recently, the maturation of design theory over time has also been acknowledged [16, 17]. However, there is a lack of advice on how to facilitate theoretical maturation and integrate DSR theory with developments in practice as well as in related research fields; i.e., a guideline that deals with the issue of enriching related search spaces through transferring and combining knowledge.

Our proposal is to extend the notion of search from its current restriction to design to also encompass a search for problem contexts, generative mechanisms, and the evidence of outcomes [19]. When the searches are conducted by different individuals, the accumulation of knowledge relies on the occurrence of positive feedback on the system level [6]; moreover, for knowledge to accumulate, a synthesizing social process of knowledge creation and evaluation by individuals [20] is needed to transfer and combine knowledge over time and between domains.

Following Denyer et al. [19], we suggest focusing on four structuring elements for defining and linking the search spaces of knowledge accumulation. These search spaces integrate fragmented knowledge into propositions that practitioners, designers, and researchers can use, while also contributing to a network of increasing specialization and the reuse of theoretical knowledge [6]. CIMO logic combines the problem, in the context (C) of a specified intervention (I), with identified generative mechanisms (M) that have been observed to produce outcome (O). Next we define the elements of CIMO logic in the domain of IS research and practice.

2.1. Problem in Context (C)

Based on Denyer et al. [19], we define Problems in Context (C) for the domain of IS as:

The outcomes that different actors aim to achieve and the surrounding (external and internal environment) factors that influence the actors.

In the domain of information systems, problems in context include features such as business objectives, available resources, risk factors, organizational politics, and power, the nature of the technical system, and system interdependencies.

Interventions are always embedded in a social system and, as noted by Pawson and Tilley [18], will be affected by at least four contextual layers: the individuals, their interpersonal relationships, the institutional setting, and the wider infrastructural system. For design science research, it is of importance that changes in the problems in the context of interest to practice are recognized.

Evidence-based management theory [10] emphasizes the importance of recognizing the problem in context when setting a firm's strategic objectives. The usefulness of evidence-based management to practice is postulated as improving managerial decision-making capabilities by infusing research outcomes into the decision-making process of a firm.

This very same understanding of the problems in the context of decision makers are important for design science researchers who are interested in producing a viable artifact and in developing solutions that are important and relevant to the business problems of the day, according to the explicit guidelines of Hevner et al. [7]. However, design science research does not dwell on the means for recognizing and transferring the understanding of the problem in a context, despite the importance of the business problems in DSR. Walls et al. [21] characterize the business problems as the meta-requirements and ultimate goals for the research echoed by Peffers et al. [23] and Sein et al. [8].

2.2. Intervention (I)

Based on Denyer et al. [19], we define the Interventions (I) for the domain of IS as:

Actions or artifacts used to influence outcomes.

Examples of interventions are changing leadership style, use of planning and control systems, training, and performance management. It is important to note that it is necessary not just to examine the form and function of the intervention, but also how it is implemented in particular instances. This is because interventions carry hypotheses with them, which may or may not turn out as expected; e.g., "timely access to relevant and reliable information will lead to faster and more accurate decision-making."

Interventions reflect the search for solutions to problems, and it is the search space Hevner et al. [7] focus on. According to Hevner et al., design is essentially a search process to discover an effective solution to a problem. The means for such a search are the set of actions and resources that are available to a particular solution.

Sein et al. [8] have illustrated this with specific tasks in the problem formulation stage; more specifically, in terms of formulating initial research questions and casting the problem as an instance of a class of problems. Nunamaker et al. [22] and Peffers et al. [23] have used theory development as a term for this search for the appropriate design of an intervention. The search for appropriate interventions is hypothesis driven and relies, according to Klahr and Simon [4], on expertise and plausibility to determine the order in which hypotheses are developed and tested.

2.3. Outcome (O)

Based on Denyer et al. [19], we define Outcomes (O) for the domain of IS as:

Intended and unintended aspects of an intervention.

Examples of outcomes are success or failure by actors to adopt, a change in performance of actors, or a change in dependency relations between actors. Attention to outcomes is particularly important for any knowledge structure, or methodology, which supports the accumulation of knowledge and theory. The reason for this is that interventions may work out as intended, but they also may have unintended consequences, which can be highly valuable; consider the discovery of penicillin by Alexander Fleming[1] in 1928 when he noticed that a Petri dish containing Staphylococcus plate culture he mistakenly left open was contaminated by blue-green mold that formed a visible growth. This opened the pathway to the development of penicillin as a medicine. Therefore, the correct recognition of unintended consequences is a driver of change [24] and the incorporation and harnessing of the phenomena is a possible path to technological invention [1].

The search for outcomes relies on evaluation. Hevner et al. [7] have listed five tactics for the evaluation of outcomes. Observation through case studies provides in-depth views on how an artifact performs in a particular problem context, while multiple case studies provide observations on its use in different organizations or use domains.

Outcomes can also be evaluated by focusing on the artifact directly, such as in the optimization or performance analysis of the artifact, experiments, and simulations. Further tactics are functional (black box) and structural (white box) testing, and "a proof-of-concept" type argumentation to evaluate the outcome of introducing an artifact. Such methods link outcomes in a direct and observable way to hypothesis testing or theory development. In addition, Klahr and Simon [4] have identified four types of evaluation methods: historical and laboratory studies; direct observations; and computational methods. The connection with Hevner et al. [7] is easily observable.

2.4. Mechanisms (M)

Based on Denyer et al. [19], we define the Generative Mechanisms (M) for the domain of IS as:

The mechanism that, in a certain context, is triggered by the intervention to produce an outcome.

[1] http://en.wikipedia.org/wiki/Penicillin

For instance, the sharing of customer feedback and requirements information with front-line employees creates opportunities for those employees to contribute to service development and design beyond their normal sphere of interest, which then prompts participation and responsibility, offering the potential of long-term benefits to the organization.

Outcomes need to be explained before they can be transferred and combined in other problems, in contexts, and for guiding the better design of interventions. The outcomes, both intended and unintended, need to be represented and described to identify the generative mechanisms that explain what works and why. The generative mechanism deals with the fundamental challenges to effective action in contexts that involve numerous human actors and related artifacts [25], such as how different actors that are involved in design and adoption of a novel solution perceive the intended use, as well as the design itself [26]. Attention to the identification of generative mechanisms is important to account for observed outcomes and the ability to only rely on field-tested design propositions [9, 15], while avoiding a waste of time and resources on fashions that mimic the insightful use of artifacts and management practice [27].

3. Transfer, combination, and evaluation of theoretical knowledge

Our argument is that there is a need for further understanding of how theoretical knowledge accumulates. The need is related to the *transfer*, *combination*, and *evaluation* of DSR theory. In the following, we go through these three issues and the relevant literature.

3.1. Transfer

First, there is a need for transfer of theoretical knowledge in DS research. Different actors cannot build and use a common theoretical knowledge base insofar as it is difficult to link different types of searches. In an organizational setting, different actors are responsible for formulating the strategy, design, and use of artifacts. When reliable, timely, and relevant DSR theories can be found, the role of the knowledge base is dominant, but when reliable DSR theories are not readily available, different actors rely on trial and error [28]. For example, in the context of inter-organizational operations, a lack of DSR theory restricts the ability of an organization in redefining strategic purpose as potentially useful technologies become available; while, at the same time, the design and implementation of technology-based interventions is hampered by a lack of strategic direction [29].

3.2. Combination

Second, in the absence of a mature DSR theory, the combination of solutions from previous build cycles and different domains is more difficult to achieve. Theoretical knowledge accumulation is needed to facilitate design by combinations and for applying the appropriate design to the problem context at hand. A sufficient structure is essential in the social process of accumulating theoretical knowledge to enable an evaluation by knowledgeable outsiders [20]. With sufficient structure and clarity, these outsiders may, for example, in the context of the service design, be potential customers [30]; or, more generally, entrepreneurs searching for opportunities to realize their business ideas [31].

The actual transfer of knowledge is important for accumulation of DSR theory, but just as important is improving the potential access and links between practical design knowledge, which is created and evaluated in parallel processes in human society. In the absence of a means of structuring and communication between designers, managers, and scholars, it is more difficult to find and use results from previous work and contribute to the efforts of others. The combination and transfer of knowledge is, consequentially, reduced to the combination and transfer of artifacts with little supporting theoretical knowledge [1].

3.3. Evaluation

Finally, in order to transfer and combine theoretical knowledge, it is essential that the knowledge base be reliable. This is the aspect of accumulation of theoretical knowledge that has received the most attention (see, e.g., [9, 10]). This aspect is important, as different actors need to rely on and trust the theoretical knowledge base in order to successfully reuse and combine the theoretical knowledge. Furthermore, it is important that sufficient evidence can be found for a credible theory that explains the different outcomes of design interventions in different contexts [15].

4. Logic for DSR theory accumulation

In the following section, we present the means for supporting the transfer, combination, and evaluation of DSR theory between search spaces. We propose introducing CIMO logic to structure both the relationship between design theory components and different search processes to facilitate the evaluation, transfer, and combination of DSR theory over time and between different types of knowledge domains. This approach for linking the search for and accumulation of knowledge is summarized in Table 1.

Links between three spaces, corresponding to a problem in context, intervention, and knowledge, have been proposed by Hevner et al. [7]. The difference to that proposition is specifying design and outcome as being distinct, adding a fourth search space. The addition makes it possible to introduce CIMO logic to describe the transfer and combination of DSR theory components proposed by Gregor and Jones [13].

The relationship between CIMO and DSR theory is summarized in Table 1 and elaborated below.

Table 1. CIMO logic to structure design theory [13]

Search Space Dynamic	Use of CIMO logic	DSR Theory Components
Problems in Context ←→ Intervention	Problem in the context for formulating an intervention	Purpose and scope
	The role of intervention in solving different problems in context	The principle of form and function
Interventions ←→ Outcomes	Interventions to be tested for outcomes/ hypothesize outcomes	Testable propositions
	The evidence of intervention outcomes	Expository instantiation
Outcomes ←→ Mechanisms	Outcomes to be explained by mechanisms	Artifact mutability
	The recognition of the mechanisms leading to outcomes	The principles of implementati on
Mechanisms ←→ Problems in Context	Mechanisms to recognize when defining what is the problem in context	Justificatory knowledge
	The problem in the context for defining the mechanisms of interest	Constructs

The proposition rests on the notion that representing the structure and logic of DSR theory components by using CIMO makes it easier to understand how design theory components are related, which in turn, enables DSR theory to be more easily evaluated, transferred, and combined.

First, we articulate the dynamics of theoretical knowledge transfer and combination between problem contexts and interventions, and vice versa. Focusing on the problem context and searching for appropriate interventions is the basis for conventional problem solving. The result of linking a problem in context to intervention is a description of purpose and scope in the anatomy of a DSR theory.

The purpose and scope [13] is a transfer of meta-requirements, or goals, to specify the type of intervention; and, in conjunction, also defines the scope, or boundaries, of the DSR theory. Vice versa, when considering how particular interventions can solve problems in different contexts, CIMO logic can be used to link an intervention to other potential problem contexts. This type of solution spotting [33] is the basis for formulating the principles of form and function [13] and provides a mental model, abstract "blueprint," or architecture that describes how an intervention, either an artifact or method, addresses a range of different problems in context.

Second, interventions need to be evaluated in the terms of outcomes; vice versa, outcomes should have a bearing on the design of interventions. The application of CIMO logic is to facilitate the consideration of possible innovative interventions that can be introduced and evaluated in practice. Such hypothesized and testable propositions are a central component of DSR theory development [13].

The search for an appropriate design of interventions relies on the expertise of the researchers to assess plausibility in determining the order in which hypotheses are developed and tested [4]. Vice versa, outcomes in the form of the implemented intervention (expository instantiation) may in iterative cycles become the basis for further developments of an intervention through combination. The use of CIMO logic aids in recognizing and dealing with *unexpected outcomes*, and the use of this recognition informs the design of different instantiations. This use of expository instantiations contributes to the accumulation of design theory [13], both as an expository device and for the purposes of testing, as expository instantiation is also critical for many methods of evaluation.

Third, outcomes need to be explained in terms of generating mechanisms, and the understanding of mechanisms needs to be applied systematically to reach desired outcomes. The application of CIMO logic helps identify which outcomes have explanations and which do not. The different outcomes from actual use reveal the mutability of the artifact/intervention [13]; i.e., the anticipated and unanticipated range of states resulting from the intervention. Vice versa, the recognition of the mechanisms leading to different outcomes will assist in formulating the effective principles of implementation [13]; more specifically, a description of processes for deploying the intervention (such as a product or method) to reach the desired outcomes and to avoid those that are undesired.

Finally, when viewed from a CIMO logic perspective, the generative mechanisms and problems in the context can also be linked in two ways. Inquiries as to whether known mechanisms are affecting a particular managerial problem can lead to the recognition of a new opportunity.

March and Simon [34, p. 155] call the combination of generative mechanisms and a problem in a given context "recognition." Inquiries may, for example, support the recognition of changing business needs; i.e., new ends can be conceptualized for a particular problem situation, or new problem situations may be conceptualized by considering the introduction of technology-based interventions.

Managers who correctly recognize relevant mechanisms can better define the problems in the context. In terms of DSR theory anatomy, such recognition is termed as justificatory knowledge or kernel theories [13, 21]. Going in the other direction, CIMO logic can aid in the formulation of the managerial problem in terms of the need for theoretical attention and explanation. The formulations of such constructs [13] for developing generative mechanisms are representations of the entities of interest in the accumulation of a DSR theory.

Our proposed use of CIMO logic for accumulation of DSR theory is summarized in Figure 1. Next, we provide an illustration of the logic in action through two exemplars drawn from jet engine and search engine development.

5. Illustrative Exemplars from Jet Engine and Search engine Development

Solving a design problem involves interaction between the four search spaces: problem in context, interventions, outcomes, and mechanisms. Depending on the problem in context, the accumulation of knowledge from the search spaces follows different patterns of convergent and ensemble change, with important implications for the accumulation of the knowledge base. The value of CIMO logic is primarily to be found in situations where developments in one search space needs to be changed (through transfer and combination) with searches in other search spaces.

For engineering problems where there is a consensus of the task to be achieved, convergence and accumulation of the knowledge base is straightforward once the problem to be solved is properly understood [1]. Significant changes and insights only rarely affect the structure of knowledge and direction of design theory development.

For example, consider the problem in context (C) of constructing an aircraft engine for high altitudes.

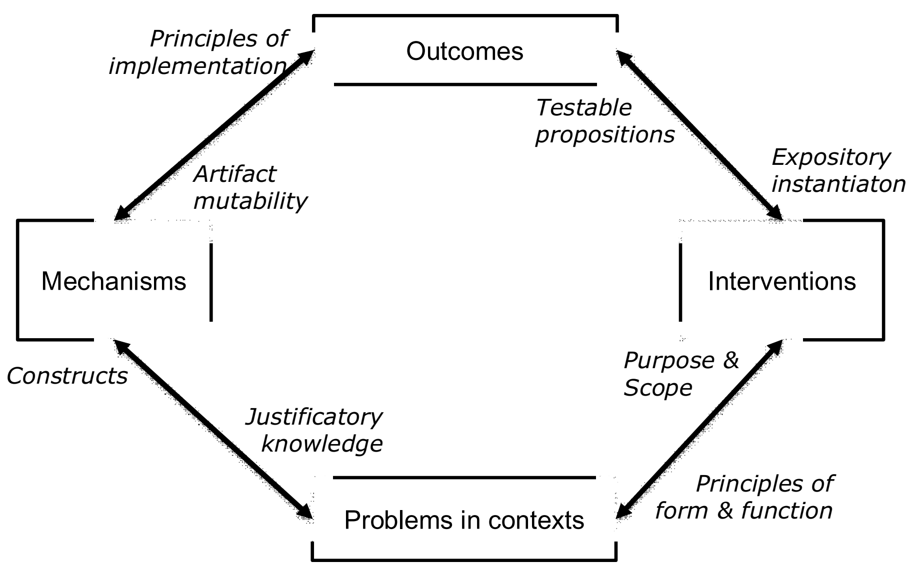

Figure 1 Logic for design science research theory accumulation

Many and very different interventions (I) were initially attempted by different actors, but produced outcomes (O) that were either failures or impractical. To design a working aircraft engine for high altitudes – a jet engine – Whittle needed to first understand the mechanism (M) of how a turbine could be used at high altitudes to produce a propelling jet stream. The basis for this invention was, thus, a transfer and combination of knowledge between search spaces, more specifically the artifact mutability of a turbine (transfer from I to M) combined with the recognition that a turbine can be used to achieve the goal of high-altitude flight (combination of M and C), leading to the still continuing and convergent accumulation of knowledge regarding jet engine design.

However, the problem of knowledge accumulation is much more challenging in many applied settings, such as information systems development, where there are many actors and co-designers present with possibly different objectives (incongruent Cs) and competing designs (divergent Is), leading to temporary outcomes and a difficulty in identifying relevant mechanisms. For example, in search engine design, there are different actors in the problem in context with their own distinct objectives that they pursue through designs of their own. When successful, an actor may render another actor's design obsolete, as – for example – search engine optimizers do when helping firms design Web pages that show up better than intended by the developers of Internet search engines. The above effort, when successful, would force search engine designers, such as Google and Yahoo, to redesign their search engines [35, p. 271]. However, by starting selling advertisements that respond to specific user searches, search engine designers have responded in turn by making the designs of optimizers less attractive to owners of Web pages.

In such ensemble problems with contexts, the accumulation of knowledge regarding designs and outcomes does not converge, and understanding of the mechanisms (M) that explain outcomes (O) needs to continuously adapt to changes in interventions (I), as well as problems in contexts (C). This does not, however, mean that theoretical knowledge cannot be accumulated and structured. The challenge is in recognizing the effect of ensemble changes of problem contexts and interventions, as well as the possibly different mechanisms invoked, leading to success or failure in outcomes for different actors. To achieve satisfactory and progressive outcomes, a combination of new and pre-existing designs are required [1], but in addition, a knowledge structure is needed to support the combination of new and pre-existing objectives of different actors, such as designers, users, and managers [32], as well as explanations of outcomes. This is the purpose for which CIMO logic was originally developed [19], and for which we propose a similar use in design science research.

6. Implications for research

The paper contributes by proposing logic for the structuring of design science research theory using CIMO. The proposal (see Table 1 and Figure 1) is a means for facilitating the access, combination, and evaluation of design science research. Our work addresses the concern in DSR that attention has been given primarily to the search process (see, e.g., [7, 8]), while the issue of the theoretical knowledge base and how to structure it to make it accessible has not been sufficiently addressed.

We emphasize three meta-level design problems [21] to be addressed: transfer, evidence, and combination. Firstly, the four CIMO elements are a structure that enables individuals and "fields" to identify and access potentially useful knowledge of others (i.e., transference). Second, the four DSR theory elements of the constructs, form and function, instantiations, and principles of implementation constitute an accumulated base of "evidence" that can be used when considering new combinations. Finally, the four DSR theory elements of justificatory knowledge, purpose and scope, testable propositions, and artifact mutability constitute a process for modifying designs through the transfer and combination of knowledge.

To enable reuse of DSR outputs, a more fundamental level than design theory may be necessary. We see that a more basic level of CIMO logic would be useful in order to assist different actors in understanding the links between parallel search spaces related to a particular design and linking to theoretical knowledge bases produced by previous search processes. The introduction of a more basic level of theoretical structuring can potentially reduce the "bounds" of rationality through the mechanism of making elements of the knowledge base more easily accessible and easy to combine.

We argue that the proposed *logic for DSR theory accumulation* is not only intended for the evaluation of a particular DSR theory, but also a methodology for developing theory through incremental and iterative theoretical accumulations of knowledge, which is likely to occur during a longitudinal project or several projects. Our objective has been to point out the need for further understanding of how a design science research theory emerges as an outcome of research efforts over time. DSR theory components, as described by Gregor and Jones [13], are not – on their own – sufficient to facilitate the effective use and accumulation of a theoretical knowledge base.

Finally, we present that DSR theory components are, in the presence of an accumulated knowledge base, available to a limited degree from the outset but become increasingly available upon reflection, once actors recognize what can be transferred and reused. In this process, we propose that CIMO logic is an aid in identifying useful elements and accessing DSR theory, which is relevant to the search process by combination.

7. Implications for practice

The managerial implications of making the combinatorial nature of theoretical knowledge accumulation and use more transparent through the application of a structuring logic are likely to facilitate the task of taking evidence-based action. In the absence of a structured theoretical knowledge base, this is a claim that is not currently possible to substantiate in the IS domain. However, by reference to domains; e.g., [10], where the ambition to provide a structured and reliable knowledge base for practitioners has a longer history, we may infer some pertinent managerial implications.

The accumulation of a structured knowledge base; i.e. a DSR theory, can be considered to be successful when the most frequent use is in the design and implementation of interventions for practice by practitioners, not only for research by researchers. From the perspective of practice, the use of structuring logic should not be seen as a formulaic method for organizing and accessing only theoretical knowledge, but rather as recognition that, in order to find and use knowledge effectively, attention to design knowledge is warranted. In other words, the structuring logic can be used as the basis for devising practical checklists and procedures for how to identify and combine design knowledge that is useful for a task or problem at hand.

However, we see that the role of the researcher, or a trained practitioner, is critical for preparing the knowledge base for such access and use, as it requires both time and competence to conduct the systematic reviews that are a foundation of any rigorous research projects.

8. Conclusion

In this paper, we have proposed logic for design science research theory accumulation. We link CIMO logic based search of different problem spaces to the design science theory components identified by Gregor and Jones [13]. We present that the search interactions between the search spaces can be described as an iterative process using CIMO logic. We demonstrate how CIMO logic can be used to produce the eight DSR theory components identified by Gregor and Jones [13]. Thus, the iterative use of CIMO logic facilitates actors in dynamically accumulating DSR theory over time and during a research project or several projects.

We illustrate the use of described logic by two exemplars from jet engine and search engine development. When defining logic for DSR theory accumulation, we note that more attention should be placed on not only the unintended consequence of evaluating the outcomes, but also on the involvement of knowledgeable and non-partisan observers that can facilitate novel combinations of theoretical, as well as design, knowledge. The very same need for the clarity of description, measurement, and explanations of causation that is required for evaluation can also facilitate novel knowledge combinations and transfers in a social setting [6, 20].

Consequently, we see that further research is needed to fully develop the proposed use of CIMO logic. The proposed logic for the accumulation of design science research theory is based on iterations around two of four CIMO elements at a time. More research is needed to determine whether this is a sound and feasible tactic, or simply reflects a preference for a logical division of search space. Previous research by Goldenberg [33] found evidence that the best outcomes from new combinations in product innovations were achieved with focused searches of either different problems in contexts or designs of interventions. Further studies are, thus, needed to understand the possible "best" combinations between different study contexts and designs. It would also be fascinating to understand how this varies between different domains of research and artifact types.

We should also venture to other fields of design. Given the recent interest in service engineering [30], it would be highly interesting to see whether the wider service research community would consider the approach to be feasible for conducting research in its field. Similarly, we feel that the current evidence-based management research community would consider our approach interesting. The proposed logic for DSR theory accumulation similarly works for management studies that aim to develop new management approaches and methods, etc. Correspondingly, engineering researchers could also potentially find our research valuable for structuring their research and providing the means to manifest the underlying theories in designs.

Finally, it would be highly interesting to see whether the proposed logic for DSR theory accumulation could be linked to a recent proposition by Gregor and Hevner [16]. Gregor and Hevner state that design science research has different types of contributions, which they divide among three levels, according to their proposition the theoretical knowledge in DSR accumulates from more abstract to more specific knowledge; namely, starting with instantiations of artifacts, which are then followed by constructs, methods, models, design principles, and technological rules. These further accumulate towards more refined DSR theories.

References

[1] Arthur, W.B., The Nature of Technology: What it is and how it Evolves, Free Press, New York, 2009.

[2] Feldman, D.H., M. Csikszentmihalyi, and H. Gardner, Changing the World: A Framework for the Study of Creativity, Praeger Publishers, Westport, 1994.

[3] Simon, H.A., The Sciences of the Artificial, MIT Press, Cambridge, 1996.

[4] D. Klahr and H.A. Simon, "Studies of Scientific Discovery: Complementary Approaches and Convergent Findings", Psychological Bulletin (125:5), , 1999, pp. 524–543.

[5] Kuhn, T.S., The Structure of Scientific Revolutions, University of Chicago Press, Chicago, 1996.

[6] R. De Langhe, "The Division of Labour in Science: The Tradeoff Between Specialisation and Diversity", Journal of Economic Methodology (17:1), , 2010, pp. 37–51.

[7] A.R. Hevner, S. March, J. Park, and S. Ram, "Design Science in Information Systems Research", MIS Quarterly (28:1),, 2004, pp. 75–105.

[8] M. Sein, O. Henfridsson, S. Purao, M. Rossi, and R. Lindgren, "Action Design Research", MIS Quarterly (35:2), , 2011, pp. 37-56.

[9] J.E. van Aken, "Management Research Based on the Paradigm of the Design Sciences: The Quest for Field-Tested and Grounded Technological Rules", Journal of Management Studies (41:2),, 2004, pp. 219–246.

[10] R.B. Briner, D. Denyer, and D.M. Rousseau, "Evidence-Based Management: Concept Cleanup Time?", Academy of Management Perspectives (23:4),, 2009, pp. 19–32.

[11] R.S. Kaplan, "Innovation Action Research: Creating New Management Theory and Practice", Journal of Management Accounting Research, Publisher, Location, 1998, pp. 89–118.

[12] A.G.L. Romme and G. Endenburg, "Construction Principles and Design Rules in the Case of Circular Design", Organization Science (17:2),, 2006, pp. 287–297.

[13] S. Gregor and D. Jones, "The Anatomy of a Design Theory", Journal of the Association for Information Systems (8:5), 2007, pp. 312–335.

[14] G. Goldkuhl, "Design Theories in Information Systems: A Need for Multi-Grounding", Journal of Information Technology Theory and Application, (6:2),, 2004, pp. 59–72.

[15] C. Fischer, S. Gregor, and S. Aier, "Forms of Discovery for Design Knowledge", European Conference on Information Systems, Barcelona, Spain, 2012.

[16] S. Gregor and A.R. Hevner, "Positioning and Presenting Design Science Research for Maximum Impact", MIS Quarterly (37:2),, 2013, pp. 337–355.

[17] J. Holmström, M. Ketokivi, and A.P. Hameri, "Bridging Practice and Theory: A Design Science Approach", Decision Sciences, (40:1),, 2009, pp. 65–87

[18] Pawson, R., and N. Tilley, Realistic Evaluation, Sage Publications, London, 1997.

[19] D. Denyer, D. Tranfield, and J. E. van Aken, "Developing Design Propositions through Research Synthesis", Organization Studies (29:3),, 2008, pp. 393-413.

[20] Longino, H. E., The Fate of Knowledge, Princeton University Press, Princeton, 2002.

[21] J.G. Walls, G.R. Widmeyer, and O.A. El Sawy, "Building an Information System Design Theory for Vigilant EIS", Information Systems Research (3:1),, 1992, pp. 36–59.

[22] J.F. Nunamaker, A.R. Dennis, J.S. Valacich, and D.R. Vogel, "Information Technology for Negotiating Groups: Generating Options for Mutual Gain", Management Science (37:10),, 1991, pp. 1325–1346.

[23] K. Peffers, T. Tuunanen, M. Rothenberger, and S. Chatterjee, "A Design Science Research Methodology for Information Systems Research", Journal of Management Information Systems (24:3), 2008, pp. 45–78.

[24] Dennett, D. C., Freedom Evolves, Viking, New York, 2003.

[25] R. Lamb and R. Kling, "Reconceptualizing Users as Social Actors in Information Systems Research", MIS Quarterly (27:2), 2003, pp. 197-236.

[26] W.J. Orlikowski and C.S. Iacono, "Research Commentary: Desperately Seeking the' IT' in IT Research—A Call to Theorizing the IT Artifact", Information Systems Research (12:2), 2001, pp. 121–134.

[27] R. Baskerville and M. Myers, “Fashion Waves in Information Systems Research and Practice”, MIS Quarterly (33:4),, 2009, pp. 647–662.

[28] Hayes, R.H., G.P. Pisano, D.M. Upton, and S.C. Wheelwright, Operations, Strategy, and Technology: Pursuing the Competitive Edge, Wiley, New York, 2004.

[29] H.R. Johnston and M.R. Vitale, “Creating Competitive Advantage with Interorganizational Information Systems”, MIS Quarterly (12:2),,1988, pp. 153–165.

[30] A.L. Ostrom, M.J. Bitner, S.W. Brown, K.A. Burkhard, M. Goul, V. Smith-Daniels, H. Demirkan, and E. Rabinovich, “Moving Forward and Making a Difference: Research Priorities for the Science of Service”, Journal of Service Research (13:1),, 2010, pp. 4–36.

[31] S.D. Sarasvathy, “Causation and Effectuation: Toward a Theoretical Shift from Economic Inevitability to Entrepreneurial Contingency”, The Academy of Management Review (26:2),, 2001, pp. 243–263.

[32] D. K. Allen, D. Colligan, A. Finnie, and T. Kern, “Trust, Power and Interorganizational Information Systems: The Case of the Electronic Trading Community TransLease”, Information Systems Journal (10:1), 2000, pp. 21–40.

[33] J. Goldenberg, D.R. Lehmann, D. Mazursky, “The Idea Itself and the Circumstances of Its Emergence as Predictors of New Product Success”, Management Science (47:1),, 2001, pp. 69-84.

[34] March, J., and H.A. Simon, Organizations (2nd ed.), Wiley-Blackwell, New York, 1993.

[35] Friedman, T., The World is Flat: The Globalized World in the Twenty-First Century (2nd ed.), Penguin, London, 2007.