Eating Our Own Cooking: Toward a Design Science of Research Methods

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Abstract

This paper argues that Design Science is an appropriate paradigm for research into Research Methods. Research Methods are designed and created by people to achieve a specific purpose – creating new knowledge. Research methods vary in utility depending on how well they their purpose in the particular contexts and contingencies for which they were developed. Applying a DSR perspective to research methods should yield increased utility in the application of research methods, better guidance in applying them and greater confidence in achieving the desired outcomes of applying them. Based on these premises, this paper analyses the logical consequences of taking a Design Science perspective on research methods. First, it analyses the various purposes of research methods to clarify the alternative and competing design goals of research methods. Second, it analyses and characterises the types of design artefacts that comprise research methods. Third, it considers issues of the evaluation of research methods. Fourth and finally, it considered the development of design theories of research methods.

Keywords: Research Method, Research Design, Design Science Research, Evaluation, Design Theory, Research Rigour

1 Introduction

There is a long history of discussion, debate, and publication regarding research methods (e.g. Nagel 1961; Campbell and Stanley 1963; Bunge 1967; Glaser and Strauss 1967; Miles and Huberman 1994). The ideas and methods used in research have evolved gradually, especially as the research domains and purposes have evolved. The discipline of Information Systems (IS) is a comparatively recent participant in this debate. However, methodological challenges inherent in the IS domain have motivated progress toward research methods that better and more fully address the IS domain (e.g. Mumford et al. 1985; Galliers and Land 1987; Benbasat 1991; Mason 1991).

The development and evolution of research methods has often been an ad hoc and non-rigorous process, because scientific communities are social phenomena with their own social institutions and mores (Berger and Luckmann 1966; Kuhn 1970; Latour 1987). New research methods and guidelines are posited and developed, written up and communicated to the research community, generally as research essays. But key aspects of rigour in their development may be lacking. Only light consideration may be given to their intended goals and purposes; measures of effectiveness, efficiency, or efficacy; evidence that the research method meets such goals or qualities; and comparisons that provide evidence that the method *better* achieves its goals than existing methods.

This paper proposes that research methods would be better developed using rigorous design science research (DSR) approaches. A DSR approach to the design and development of new or improved research methods would provide a more rational and consistent basis for assuring both their utility and rigour. The rigour from using a DSR approach would come primarily from (a) more precisely stated design theories about research methods and (b) more rigorous evaluation of research methods. Explicating such elements may even help make the peer-reviewing of the resulting research more predictable and less capricious. A seminal paper on DSR by March and Smith (1995) provides support for the use of Design Science Research for the development of research methodology.

> *"Natural science uses but does not produce methods. Design science creates the methodological tools that natural scientists use. Research methodologies prescribe appropriate ways to gather and analyze evidence to support (or refute) a posited theory. They are human-created artifacts that have value insofar as they address this task." (p. 258)*

This paper is organised as follows. The next section reviews the relevant literature on DSR. Section three applies a DSR lens to the goals and objectives of research methods, research methods as designed artefacts, requirements for evaluation of research methods, and design theories in research methods. Section four summarises the paper and identifies areas for further research.

2 Key Aspects of Design Science Research for Research Methodology

This section considers relevant literature from the field of Information Systems (IS) on Design Science Research (DSR). Interestingly, among the work on DSR in IS, no one has attempted to define it. We will define DSR as "Research in which a new solution technology is invented". By solution technology, we mean any kind of human designed artefact, whether product or process, tool, methodology, technique or any other means for achieving some purpose. By invention we mean creation, design, improvement, adaptation, not just 'pure' invention from scratch (which may not exist anyway).

In this section, we consider in turn research paradigms and goals, design artefacts, design theories, and evaluation in DSR.

2.1 Research Paradigms and Goals

Orlikowski and Baroudi (1991) asserted that the then dominant paradigm of IS research was one based on a positivist philosophy. They then argued that other philosophical positions were relevant, including interpretive and critical philosophical positions. The interpretive position contrasted with the positivist position fits the subjective-objective dimension in Burrell and Morgan's (1979) paradigmatic framework. The critical philosophical position roughly fits the radical change end of the regulation-radical change dimension of their paradigmatic framework. A fourth research paradigm is that of the research essay, in which one makes an argument based on logic and reasoning. There is a long tradition of this in philosophy. Galliers (1991) identified this as a research approach, but did not distinguish it as a paradigm. He called it subjective/argumentative, but we do not see that it is necessarily subjective. However, it may be subject to faulty reasoning. The different research paradigm has implicitly been recognised by the Journal of the Association for Information System editorial comment by Hirschheim (2008) giving guidelines for "conceptual papers". Design Science can be considered as a fifth research paradigm that is fundamentally different from other paradigms. It seeks to create new ways and means to solve problems and make improvements, through the invention, design, and development of new solution technologies. We therefore classify research into five different paradigms: Positivist, Interpretive, Critical, Design Science, and Logico-Argumentative.

2.2 Design Artefacts

March and Smith (1995) established the terminology of Design Science in IS, relating it to Herbert Simon's ideas of sciences of the artificial (Simon 1969; 1996) and proposed design science as a research approach. They identified four kinds of design artefacts as the outputs of DSR: constructs, models, methods, and instantiations. Constructs are concepts that are used to describe a problem and specify its solution. They define models as "a set of propositions or statements expressing relationships among constructs" (p. 256) that can be used to "represent situations as problem and solution statements" (p. 256). They define methods as "a set of steps (an algorithm or guideline) used to perform a task" (p. 257). Finally, they define instantiations as "the realization of an artifact in its environment" (p. 258). Interestingly, the above artefacts do not include "design" per se. However, the model artefact could be viewed as a design, in that it includes "solution statements" (p. 256). A design can then be conceived of as different constructs (the design components) and statements about relationships between them. Gregor and Jones (2007) distinguish two different kinds of technologies that can be designed: product artefacts and process artefacts. A product artefact is a thing, such as a tool, an object, or a system. It can be either physical (e.g. a computer) or abstract (e.g. a diagram notation). A process artefact is similar to a method (March and Smith 1995).

2.3 Design Theory

Design Theories are formalisations of the knowledge resulting from Design Science Research. Researchers generally consider that all high quality research should generate, evaluate, or refine theory. Walls et al (1992) argued that a proper design theory should have seven components as shown in figure 1: meta-requirements (a general set of requirements that a generalised solution would address), meta-design (a generalised design that could be adapted to a particular problematic situation), a design method (for adapting the meta-design to the particular problematic situation), kernel theories informing the meta-design (according to the meta requirements), kernel theories informing the design method (according to the meta-requirements and meta-design), testable hypotheses to test the meta-design and testable hypotheses to test the design method. They also state that design theories are prescriptive in guiding designers as to what they should do.

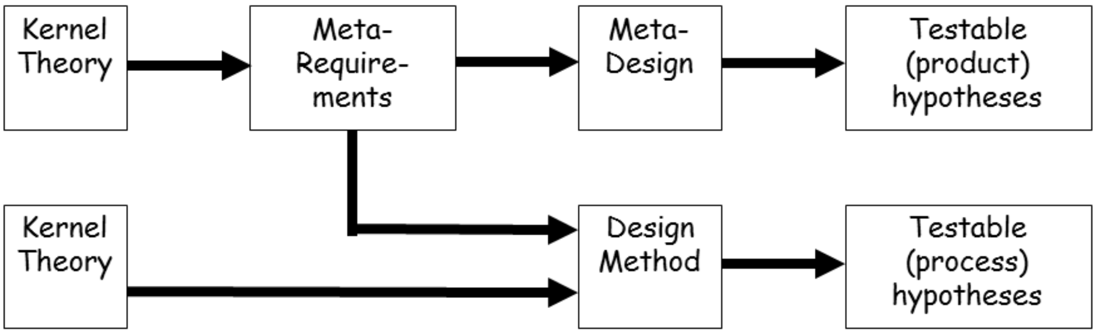

Figure 1: Structure of a Design Theory (Walls et al, 1992)

Venable (2006b) asserted that kernel theories and testable hypotheses are not part of a design theory *per se* and that a design method is unnecessary in a design theory. He advocated a simpler, non-prescriptive form of theory (which he termed a "utility theory") containing only the problem space to which a design theory applies, a solution space describing a design, and a relationship between them asserting that the design has utility of some kind (efficiency, effectiveness, etc.) with respect to the problem space. Relationships between components of the problem space and between components of the solution space should also be part of the design/utility theory. Gregor and Jones (2007) developed an alternative form of design theory with eight parts: Purpose and scope, Constructs, Principles of form and function, Artefact mutability, Testable propositions, Justificatory knowledge, Principles of implementation, and an Expository instantiation (optional). Baskerville and Pries-Heje (2010) reacted to the complexity of the formulations of ISDTs and design theories in Walls et al (1992) and Gregor and Jones (2007). Their simplified formulation of “explanatory design theory” includes only “general requirements” and “general solution” as well as an explanatory relationship between the two of them (i.e. the general solution explains how to address the general requirements).

2.4 Evaluation

Evaluation is an essential activity in Design Science Research (Nunamaker et al. 1991; March and Smith 1995; Hevner et al. 2004; Vaishnavi and Kuechler 2004; Venable 2006a; 2006b; Peffers et al. 2008). Evaluation is what makes DSR a science. Without evaluation, asserted design theories, utility theories, or technological rules are just untested theories, conjectures, and hypotheses; there is no evidence to back them up. We identify five evaluation issues. One issue in DSR concerns what the evaluand (the artefact being evaluated) is: process or product; construct, model, method, or instantiation; or design theory. A second issue concerns what aspects or qualities of the evaluand are to be evaluated. Artefacts are evaluated for their fitness to purpose. Purposes are extremely varied, but one can identify some key characteristics, such as Checkland’s five E’s: efficiency, effectiveness, efficacy, (a)esthetics, and ethicality (Checkland and Scholes 1990), which are aspects of utility. Venable (2006a) also notes three aspects of evaluation: (1) evaluation of efficiency, effectiveness and efficacy (i.e. utility), (2) evaluation of the artefact in comparison to other solution technologies (i.e. relative utility), and (3) evaluation for undesirable impacts (i.e. side effects). A third issue concerns the rigour of the evaluation. There are two senses of rigour. The first sense is whether an improvement or achievement of purpose can be attributed to the evaluand (i.e. its efficacy), or alternatively whether it could be caused by some confounding variable. The second sense is whether the evaluation can work within the myriad complicating aspects of real use, i.e. its effectiveness. The fourth issue is the choice of evaluation method(s). Hevner et al (2004) suggest analytical, case study, experimental, field study, and simulation. Venable (2006a) distinguishes between artificial evaluation and naturalistic evaluation. Artificial evaluation supports controlling for confounding variables (to evaluate efficacy) while naturalistic evaluation gives “the proof of the pudding” (evaluating effectiveness). Naturalistic evaluation occurs when one has real users, using the real technology on a real problem or in a real context (Sun and Kantor 2006). Artificial evaluation methods include various forms of simulation or experiment while naturalistic evaluation includes case studies, surveys, field studies, and action research. Pries-Heje et al (2008) identify different strategies for conducting DSR evaluations, contrasting *ex ante* with *ex post* evaluation and artificial vs naturalistic evaluation, giving a 2x2 matrix of strategies. Venable et al (2012) further expand on Pries-Heje et al (2008), proposing a framework for helping design science researchers to select among different evaluation methods to better design the evaluation part of a DSR project. A final issue is the potential for errors in evaluating a new technology. Baskerville et al (2007) analyse and describe some key areas where evaluation can go wrong or lead to unfaithful, inaccurate, or erroneous results, including both type 1 (false positive) and type 2 (false negative) errors.

3 Analysis of Research Methods Using a Design Science Research Lens

This section considers what lessons may be learned from applying Design Science Research to research methods and how DSR might improve the rigour of research methods. We look at four main areas in turn: goals (and constraints) of research methods, design artefacts in research methods, the need for evaluation of research methods, and design theory in research methods.

3.1 Goals of Research Methods

Goals of research methods include both primary goals and practical goals that enable their effective use. We discuss goals first, then implications from a DSR perspective.

3.1.1 Primary goals

The primary goals of research methods include both general goals and goals specific to each research project. Rigour and relevance are general goals desired of all research and research methods. Research methods must also be appropriate for answering the specific research question or achieving the specific goal of the research. Rigour is concerned with the reliability of research. Properly following a research method should ensure that the research findings are correct or that the probability of the findings being incorrect is sufficiently low. Relevance is concerned with whether the findings are useful – either to theory and further research or to practice. While following a research method may not ensure relevance, some research methods may be more amenable to investigating topics that are relevant. There are several kinds of research questions, including questions concerned with theory testing (and extension), theory building, understanding and explanation, prediction (*cf.*Gregor 2006), evaluation, invention of new technologies to solve problems, or achieving human emancipation. Different research methods are more or less appropriate for answering different kinds of research questions. There are also several different kinds of research field or domain, including physical sciences, biological sciences, behavioural sciences, social sciences, and various forms of applied technical sciences and socio-technical sciences. This list is very high level and is not comprehensive. Different research methods will be more or less appropriate for research in these different domains.

3.1.2 Practical goals

There are many practical goals for research methods that affect their ability to be applied and to achieve the primary research goals given above, including ease of learning, ease of use, cost, time required, facilities or other resources required, access to research subjects, ability to deal with more people and research subjects, and depth of engagement with research subjects.

For novice researchers or researchers trying out a new methodology, ease of learning is an important issue. Once learned, a research method that is easier to use will be preferred.

Research methods that have lower costs are preferable. Costs include time/labour, tools (e.g. computers, software), and other resources (e.g. communications and physical space) needed to apply the research method

Some research methods require less access to research subjects (people or organisations) than others. Access is often difficult to obtain, so low requirements for access are preferable to high requirements for access.

Some research methods are more suitable to dealing with research questions that concern larger numbers (or breadth) of people while others support a greater depth of engagement with research subjects.

Practical goals above are often in the form of constraints on available researcher time, expertise, funding, access to research subjects, and others. The above list is probably not comprehensive.

3.1.3 Lessons from DSR

The goals described above represent meta-requirements for research methods. Research methods represent meta-designs. Goals or meta-requirements form contingencies that are addressed with differing levels of utility by different research methods.

A key issue is that the number of goals and constraints is fairly large and to some extent they conflict. Evaluating different contingencies is complex and difficult as it is a combinatorial problem without hard yes/no answers. However, the provision of a clear system of design theories with research goals as the contingencies would aid in selecting an appropriate research method for a particular research situation. The approach used in the Design Theory Nexus system described in Baskerville and Pries-Heje (2008) for helping managers to select an appropriate change management methodology might also be applied to a system to help selection of research methods.

3.2 Design Artefacts in Research Methods

What kind of design artefact is a research method? A research method is clearly a *process (method) artefact*. Research methods often (always?) make use of various tools, techniques, and frameworks for organising and doing the research work. These are clearly *product artefacts*. Descriptions of how to use a tool, technique, or framework are in turn process artefacts. Research methods clearly are a class of March and Smith's (1995) method design artefact.

From the Walls et al (1992) perspective, the research method itself seems to be a meta-design, which is aimed at achieving the meta-requirements of research (see the goals discussion in section 3.1 above).

Venable (2006b) emphasised that it is important to clearly identify and precisely define the components/constructs in the problem space and the solution space, in this case the goals and requirements of the research method and the research method itself.

Importantly, tools and techniques may sometimes be used with other methods than the methods for which they were developed. Any attempt to conduct DSR on research methods needs to consider the possibility that research tools and techniques have uses both as part of and outside of any particular research method.

3.3 The need for evaluation of research methods

A key aspect of DSR is evaluation of new technologies (including research methods).

3.3.1 Why evaluate research methods?

Currently, we lack rigorous evidence of the effectiveness, efficiency, and efficacy of research methods. Some evidence clearly is provided by the evident progress of human knowledge. Other evidence has been developed through rational argument in research essays (i.e. in the logico-argumentative paradigm). However, without more rigorous evidence, how do we really know that research methods are effective? We also lack evidence about whether research methods achieve other desirable, practical goals – e.g. ease of learning, ease of use, and time and resource requirements. Moreover, we especially lack evidence about the relative efficiency and effectiveness of research methods, i.e. compared to each other. In order to make better judgments in the choice of research methods, it would be very helpful to have better evidence than our currently ad hoc assertions about them.

3.3.2 How could we evaluate research methods?

Like other designed artefacts, research methods should be evaluated for their utility in achieving their goals, including primary goals of rigour and relevance, suitability to type of research questions and goals, and suitability to type of research domain or topic, as well as secondary, practical goals.

Rigour assessment during the reviewing process is rather subjective and often simply confirms that an established research method has been followed, assuming that the outcome will therefore be correct, even though the research method itself may not have been rigorously evaluated.

However, perceived rigour is not clear evidence of the rigour of a research method. Convincing evidence would come from the detection of errors in findings and determining error rates. Where errors are found in findings, the research method itself is in some way responsible (after all, it didn't prevent the error), but additional causes are possible (e.g. misapplication of the method). Finding errors would require triangulation of findings through other research, which may not be possible or thought to be worth the research expenditure.

The rigour of some research methods, especially positivist ones, can be demonstrated through mathematical analysis or proof.

To assess whether research methods not amenable to mathematical analysis achieve an acceptable level of rigour, research conducted could be subjected to critical analysis and ratings of rigour. The rigour ratings could then be compared and correlated across projects using different research methods. Mixed- and multi-method approaches would complicate these analyses. It may also be helpful to analyse failed research projects, where outcomes are not accepted for publication. One might also consider whether a research method correlates with high or low quality journals.

While factors other than research method used are likely more important drivers of relevance, nonetheless, one could attempt to assess or rate relevance (e.g. of research projects in the literature) and correlate relevance ratings with the research method used.

One can also analyse whether a research method used correlates with types of research questions or domains of research. To a great extent, rational argument can (and has been) used for this, but it may be useful to identify anomalies in the extant research.

Assessment of the performance/utility of research methods in achieving goals in other, practical areas may be more fruitful. One could, for example, survey users of various research methods about their perceptions of ease of learning and ease of use of research methods, tools, techniques, etc. One could evaluate resource consumption by gathering data on time required, resources consumed, costs, etc. and correlating them with research methods.

Where a method is new and untried, evaluation is largely limited to analytical kinds of evaluation, e.g. rational argument, surveys or focus groups with experts in research methodology, or possibly some form of simulation. Empirical, naturalistic evaluation will likely be very limited at first, with limited trials, probably using qualitative evaluation methods.

3.3.3 Pitfalls and difficulties of evaluation of research methods

Rigour is assessed in the reviewing process rather subjectively. Care must be taken to try to reduce the variability by setting out very specific criteria, preferably objective criteria.

Relevance is more likely due to choice of research topic and domain than the research method. However, some part of relevance (e.g. very new or contradictory findings) may be due to the research method used. This needs careful assessment when evaluating a research method.

Research methods need to be applied properly or one isn't actually evaluating the research method (Baskerville et al. 2007). Misapplications of a research method may be attributed to the method rather than to the method user. However, if research methods are prone to misapplication, then that is a problem with the research method.

Different research projects may have different research contexts/situations, research questions, resources, staff, which means that it may be completely inappropriate to compare different research projects. Very importantly, some research projects and research method applications may present unusual rather than typical circumstances.

3.4 Design Theory in Research Methods

Design theories are formalisations of the knowledge obtained from Design Science Research, including the design of research methods.

3.4.1 Why design theories of research methods?

Theory is the way that academics communicate with each other about research (Venable 2006b). Clear, formalised design theories about research methods should reduce misinterpretation and allow research method researchers to accurately research the same topics. Design theories about research methods are important when developing new research methods as one needs to be able to clearly articulate how a new research method is different from existing ones.

Clear statements of design theories may also be useful for practitioners – in this case the practitioners are researchers. Even if one doesn't research *about* research methods, research method users can greatly benefit from clear and precise statements about them (their meta-design) and under what circumstances they have utility or should be used (their meta-requirements).

We propose that formal design theories could and should be developed for every research method. Doing so would aid the ongoing development and progress in research methods and in the long run should increase our ability to generate new, valid knowledge.

3.4.2 What should be in a design theory for a research method?

Four different forms of design theories have been suggested (Walls et al. 1992; Venable 2006b; Gregor and Jones 2007; Baskerville and Pries-Heje 2010). A design theory should use one of these and at a minimum cover a core of the parts of the design theory.

A design theory for a research method at a minimum needs three things: (1) meta-requirements (Walls et al. 1992) or equivalent, (2) a meta-design (Walls et al. 1992) or equivalent, and (3) a relationship between them. Other aspects of design theories are optional (but may be useful).

All aspects of design theories need to be stated as precise, well-defined constructs. The meta-requirements or equivalent should include and clearly state the goals (and possibly the constraints) for which the research method is suited (or possibly the level to which they are suited, such as low cost). The primary goals that should be addressed include research rigour and relevance and the level of each that can be achieved or expected, the type(s) of research question for which the method is suited, and the domain(s) for which the research method is suited. Optional goals should also be addressed by statements about the anticipated levels of ease of learning, ease of use, cost, time required, facilities or other resources required, level of access to research subjects needed, ability to deal with more people and research subjects, and depth of engagement with research subjects.

The meta-design or equivalent should include a detailed description of the research method's process, including steps, actions to take, tasks, decisions, and iterations, as well as tools and techniques to use, and when and how to use them. Descriptions of tools and techniques may refer to other design theories for detail about them.

It is also very useful to describe how to apply the methodology to create a detailed research design. This could be a separate design method, included as part of the model of the solution space, or provided separately as principles of implementation (Gregor and Jones 2007).

4 Conclusion

Research Methods are designed artefacts. The evolution and development of research methods needs a more rational basis for assuring their utility and rigour. This paper proposes that DSR could (and should) provide such a basis. The rigour would come primarily from (a) more precise and complete statements of design theories of research methods and (b) more rigorous evaluation of research methods. We have identified the primary and secondary (practical) goals of research methods, which form the meta-requirements part of design theories about research methods and serve as criteria for evaluation of the utility of research methods. We have also identified types of design artefacts in research methods, which would define the research method meta-design in a design theory. The configuration of constructs and artefacts that make up a research method are what are evaluated for how well they fulfil the research method's goals. We further identified relevant evaluation methods and issues relating to research method evaluation. Applying a DSR approach to research about research methods should enhance the quality of research methods and therefore the quality of the research conducted using them.

What we have proposed in this paper is only a first step. Work is now needed to analyse existing research methods to develop clear design theories about them. The basis for this already exists in the literature; it simply needs critical reading and formalising in design theories. Consideration also is needed re designing and carrying out appropriate evaluations of research methods, to provide evidence of their effectiveness, efficiency, efficacy, etc. in achieving their disparate purposes. Once a body of literature on design theories and evaluations of research methods is developed, there would be a clearer basis for further research on research methods.

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