WHAT ARE THE SIBLINGS OF DESIGN SCIENCE RESEARCH?

Paul Johannesson, Department of Computer and Systems Sciences, Stockholm University, Forum 100, SE-164 40 Kista, Sweden, pajo@dsv.su.se

Erik Perjons, Department of Computer and Systems Sciences, Stockholm University, Forum 100, SE-164 40 Kista, Sweden, perjons@dsv.su.se

Ilia Bider, Department of Computer and Systems Sciences, Stockholm University, Forum 100, SE-164 40 Kista, Sweden, ilia@dsv.su.se

Accepted to the SIG Prag Workshop on IT Artefact Design & Workpractice Improvement, 5 June, 2013, Tilburg, the Netherlands

Abstract

There is no common agreement on how to characterize and positioning design science research. This makes it difficult for design science researchers to communicate the ideas of design science research to students, young researchers, and researchers outside the design science research community. In this paper, we present an approach for supporting the positioning of design science research in respect to key notions such as social science, research strategies, practice research, and action research. The approach is based on Wittgenstein's notion of family resemblance, and the question addressed in the paper is: What are the siblings to design science research? Four sibling groups are presented, and the paper suggests how design science research can be compared and contrasted to its siblings within these groups.

Keywords: design science, branch of research, research strategy, practice research, action research, the scientific method, family resemblance

1 Introduction

Design science research in information systems is still in a process of finding its identity. As noted by Baskerville (2008), there is still not a broad agreement on terminology, theory, methodology, evaluation criteria, etc. It is unclear how design science research should be characterized and positioned with respect to notions like research paradigms, research methods, and branches of science.

The disagreements about design science research make it difficult for design science researchers to communicate about their results and methods, and it also hinders the spread of design science research to students, young researchers, and researchers outside the design science community. Thus, there is a need to define and position design science research. However, it will probably never be possible to obtain a complete agreement on what design science research is. Noting this, Baskerville (2008) suggested instead to agree on "what design science is not", inspired by the work by Sutton and Staw (1995), who investigated the notion of theory in management science by elaborating on "what theory is not". Baskerville goes on to argue that design science is not design, not design theory, not an IT artefact, not methodology, not action research, not computer science, not a separate academic discipline, and not new.

Another approach to positioning design science research is to compare and contrast it to key notions and phenomena occurring in different research communities. Some researchers have viewed design science research as a research paradigm (Hevner et al., 2004), and contrasted it to the behavioural science paradigm, while others have compared design science research to research strategies like case studies and experiments (Oates, 2005). This way of contrasting and comparing design science can be seen as attempts to identify family resemblances between design science and related phenomena. Family resemblance is a notion in philosophy, proposed and popularised by Wittgenstein (1973). The idea behind the notion is that things that are grouped together into one category do not need to share any essential common feature, but can sometimes be related only through a number of overlapping similarities. As Wittgenstein (1965) states: "if [...] you wish to give a definition [...], to draw a sharp boundary, then you are free to draw it as you like; and this boundary will never entirely coincide with the actual usage, as this usage has no sharp boundary".

Searching for different family resemblances may be a more fruitful way to characterize and explain design science research than to aim at a single definition. Thus, the question posed by this paper is "What are the siblings of design science research?"

In order to identify possible siblings, we first reviewed seminal papers in the area and textbooks that addressed design science. Based on this review, we identified four groups of siblings.

2 Four Sibling Groups of Design Science Research

In this section, four different sibling groups will be presented, positioning design science research in four different ways. The four sibling groups are: branch of science; research strategy; practice research; and scientific method and design science research.

2.1 Branch of Science: Natural Science, Social Science, Formal Science, Design Science

Design science research can be viewed as a sibling to natural science, social science, and formal science. These are sometimes called branches of science. One of these is natural science that studies natural phenomena, including physical and biological phenomena. Another branch is social science that studies the social behaviour of humans and societies. Natural science and social science can be

grouped into empirical science. The goal of empirical science, at least from the perspective of positivism, is to describe and explain the world as it exists regardless of human interests and biases. The world is out there, and can be explained by science so that people have a common understanding of it, irrespective of their backgrounds, traditions and values.

There exist other perspectives in empirical science. Empirical science influenced by the perspective of interpretivism, common in social science research, argues the social world does not exist "out there" independent of human actions and intentions. Instead, the social world is constructed by people who carry out social actions and give meanings to them. According to this perspective, certain forms of research methods need to be used. By using such methods, researchers can get close to the people who participate in the phenomena being studied and thereby better understand their views and interpretations.

Besides empirical science, there is also formal science including mathematics, logic, and statistics. These differ from empirical sciences through their method of verification, using proofs rather than empirical methods.

Several researchers can be seen as viewing design science research as a branch of science. March and Smith (1995) contrast design science with natural science, which should be interpreted as a synonym to the term empirical science presented above, including physical, biological, social, and behavioural science. According to March and Smith (1995), "natural science is concerned with explaining how and why things are, while design science is concerned with devising artefacts to attain goals". Similar to March and Smith (1995), Peffers et al. (2007) contrast design science research with descriptive research, another synonym to the term empirical science. Hevner et al. (2004) contrast design science with behavioural science, claiming that these are the two major "paradigms" in IS research.

Empirical science can be viewed as describing and explaining the actual world in the present and the past. Formal science does not restrict itself to the actual, but lays down mathematical structures that can be used to describe and explain any world irrespective of time, place, and existence. In contrast to empirical and formal science, design science research is not content only to describe and explain. It also wants to change the world, to improve it and to create new worlds. Design science does this by developing artefacts that can help people fulfil their needs, overcome their problems, and grasp new opportunities. As stated by Bider et al. (2013a): "There is a substantial difference between design science on one hand and wide spread qualitative and quantitative empirical methods on the other. The latter are aimed to investigate real life situations as-is, or as they were at some point in the past, and find commonalities between them which can give rise to a theory that explains the current or past state of affairs. [...] Focusing on the present and past in such a dynamic area as IS has a major drawback. It means that research follows the industry/practice and explains its successes and failures rather than showing new ways to proceed, as argued in (Österle et al., 2010). Design science research with its focus on generic problem solving tries to overcome this drawback. This kind of research can be considered as an activity aimed at generating and testing hypotheses for future adoption by practice".

2.2 Research Strategy: Case Study, Action Research, Experiment, Design and Creation

Design science research can be viewed as a sibling to action research, case study, ethnography, experiment and survey. These are often called research strategies or research designs.

A research strategy is an overall approach to answering a research question. A research strategy provides a structure for designing research providing a plan of action, which guides and governs the research process. In addition to a list of preferable data generation and analysis methods, a research strategy includes the general set up of the context in which the research is undertaken. Some well established research strategies are surveys, experiments, case studies, action research, grounded theory and ethnography.

One researcher, Oates (2006), claims that design science research, called "Design and Creation" by Oates, should be viewed as a research strategy on the same level as case study, ethnography, action research, experiments and surveys. According to Oates, the Design and Creation strategy is a problem solving approach that uses an iterative process with five steps, referring to Vaishnavi and Kuechler (2004): *awareness*, which is stating a problem; *suggestion*, which is expressing a design idea; *development*, which is implementing the design idea; *evaluation*, which is assessing the artefact, and *conclusion*, which is consolidating and documenting the result and the knowledge of the design process.

The view that design science research is a research strategy may seem to be overly restricted, as other research strategies can be used within design science. For example, within a design science project, surveys can be used to elicit requirements and experiments to evaluate artefacts, see Hevner et al (2004), and Johannesson and Perjons (2012). This point is elaborated by Baskerville (2008): "There is certainly room to create methods for design science, but the methods should not be equated to the field in which these operate. The field of design science involves its own particular facets of the philosophy of science. These facets involve the purpose-driven creation of artefacts and the introduction of these artefacts into otherwise natural settings".

2.3 Practice Research: Action Research, Evaluation Research, Design Research

Design science research can be viewed as a sibling to action research and evaluation research. These are sometimes viewed as forms of practice research.

Practice research produces knowledge about practices for practices and research. According to Salisbury Forum Group (2011), practice research aims to address challenges in practices and these challenges are addressed by collaborations between practitioners and researchers. A practice is a set of human activities performed regularly and is seen as meaningfully related to each other by the people participating in them. An example is the practice of dentists, who engage in cleaning teeth, drilling teeth, pulling out teeth, taking X-rays, and many other activities. When people engage in practices, they will typically need to handle natural as well as man-made objects. For example, dentists and dental nurses will repair teeth and make use of pliers, drills, X-ray machines, etc. Practices can be more or less structured or formalized. Some practices take place within organisations, e.g., the production of cars in factories or the management of customer complaints in call centres. Other practices occur in informal settings, for example, people having dinner together.

One researcher, Goldkuhl (2011), states that practice research "can take different forms, as for example, evaluation research, action research and design research". These three forms of practice research can all fit into an "anatomy" of practice research created by Goldkuhl (2011). The anatomy consists of two sub-practices of research and three target communities. The two sub-practices are situational inquiry, which is an empirical study of a concrete practical situation in a local practice, and theorizing, which means theorizing based on situational/empirical data to generate abstract knowledge. These sub-practices should deliver solutions to the three target communities: local operational practice, general practice (i.e. practice communities), and research community.

Goldkuhl´s view requires a return to the ongoing discussion of the similarities and differences between action research and design science research (e.g. Järvinen, 2007; Sein et al, 2011). Goldkuhl's analysis suggests a reinterpretation of action research and maybe also design science research, which can be a basis for contrasting and comparing them. The traditional view of action research is that it needs to contribute to both local practice and the research community, but not necessarily to general practice. Goldkuhl (2012), however, suggests an additional requirement that action research also should to contribute to general practice. Similar, the traditional view of design science research is that it needs to contribute to both general practice and the research community. An open question, however, is whether design science research needs to contribute to local practice. One interpretation, based on Goldkuhl's anatomy, is that design science research *can* contribute to local practice, while another is

that it *needs to* contribute to local practice. Goldkuhl (2011) states that practice research not contributing to local practice is an exceptional case, although not discussing design science research (called "design research by Goldkuhl) specifically.

Another open question is whether design science research requires collaboration with practitioners, which is often included in research practice definitions, see, for example the definition of practice research from Salisbury Forum Group (2011). However, there is design science research that does not include collaboration with practitioners, for example, developing an algorithm for a narrowly defined purpose, although such design science research might not be interpreted as practice research.

2.4 The Scientific Method and Design Science

Design science research can be seen as a sibling to the scientific method. According to the Oxford English Dictionary, the scientific method is "a method or procedure that has characterized natural science since the 17th century, consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses". One common version of the scientific method is the hypothetico-deductive method, which is typically divided into four steps:

1. *Ask a question.* The researcher observes some phenomenon that is novel, surprising, or interesting for some other reason. She attempts to capture the relevant aspects of the phenomenon by asking a question about it.
2. *Form a hypothesis.* The researcher comes up with and formulates a hypothesis that is able to answer the question.
3. *Deduce predictions from the hypothesis.* Assuming the hypothesis is true, the researcher identifies some consequences that must then hold, i.e., she makes a number of predictions.
4. *Check the predictions.* The researcher performs observations to determine whether the predictions are correct or not; if correct, the hypothesis is strengthened, otherwise it is weakened.

There exist several methods for design science in the literature, e.g. those proposed by Peffers et al. (2007), Vaishnavi and Kuechler (2004), and Sein et al, (2011). Johannesson and Perjons (2012) introduce a generic design science research method, inspired by Peffers et al. (2007), consisting of five activities:

1. *Explicate Problem.* The Explicate Problem activity is about investigating and analysing a practical problem. It is to be precisely formulated and motivated by showing that it is significant for some practice.
2. *Outline Artefact and Define Requirements.* The Outline Artefact and Define Requirements activity is to outline a solution to the explicated problem in the form of an artefact. Requirements on the artefact are to be determined as well, specifying which requirements are important for stakeholders. The requirements will primarily address the function and construction of the artifact, but also the relationships to its environment.
3. *Design and Develop Artefact.* The Design and Develop Artefact activity aims to create an artefact that addresses the explicated problem and fulfils the defined requirements.
4. *Demonstrate Artefact.* The Demonstrate Artefact activity uses the developed artefact in an illustrative or real life case, sometimes called a "proof of concept", thereby proving the feasibility of the artefact.
5. *Evaluate Artefact.* The Evaluate Artefact activity is to determine how well the artefact fulfils the requirements and to what extent it can solve, or alleviate, the practical problem that motivated the research.

It has been argued, e.g. by Fischer and Gregor (2011) as well as Eekels and Roozenburg (1991), that design science research methods are in several respects similar to the scientific method. The design

science research method described above is aligned with the scientific method. Its first activity, Explicate Problem, is similar to Ask a question of the scientific method, as both investigate a situation that is experienced as challenging. The difference is that in the scientific method a question is asked, while a practical problem is examined in design science research method. Step 2, Form a hypothesis, is similar to activities 2 and 3 of the design science research method, which first identify requirements on an artefact and then design and develop it. However, in the scientific method an answer is formulated in the form of a hypothesis, while design science research produces an artefact. Steps 3 and 4 of the scientific method correspond to Evaluate Artefact of the design science research method, as both intend to show that the results produced are satisfactory. Summarizing, steps 1 and 2 of the scientific method, as well as activities 1 to 3 of the design science research method, are about discovery and invention, i.e. creating a new hypothesis or artefact. Steps 3 and 4 of the scientific method, as well as activities 4 and 5 of the design science method, are about justification, i.e., ensuring that the created hypothesis or artefact is adequate.

3 Concluding Remarks and Plans for the Future

Through investigating family resemblances for design science research, this paper attempts to contribute to sense making in the design science research practice. It has been outlined how design science research can be viewed as a branch of science, a research strategy, a form of practice research, and a sibling to the scientific method. The paper has also suggested how design science research can be compared and contrasted to its siblings within these categories.

The main contributions of the presented approach are:

- it will provide a fruitful starting point for a concrete and creative discussion on the key characteristics of design science research, as it will invite discussions based on specific phenomena rather than abstract categories

- it clarifies how researchers differ in their views on design science research

The idea of this paper is contrasting design science research to key notions and phenomena occurring in different research communities, i.e. branch of science, research strategies, etc. Another promising direction to better grasp the notion of design science is to find the points of connection between design science research and other types of research, such as social science. For example, Baskerville and Gregor (2012) are providing this kind of connections and envision the fusion between social science and design science. Bider et al. (2013b) follows up this idea and suggests a methodology for a detailed investigation of the cases where empirical research methods can/should be used in a design science research project. This can be a concrete way of comparing design science research to notions such as branch of science, research strategies and research methods. The methodology is based on the authors' previous work (Bider et. al 2013a) that defines design science research as movement within and between the specific and generic situation-problem-solution spaces.

References

Baskerville, R. (2008). What design science is not. European Journal of Information Systems, 17 (5), p. 441–443.

Bider, I., Johannesson, P. and Perjons, E. (2013 a). Design Science Research as Movement Between Individual and Generic Situation-Problem–Solution Spaces. In: Baskerville, R., Marco, M. D. and Spagnoletti, P. (eds.), Designing Organizational Systems, Lecture Notes in Information Systems and Organisation 1, Springer Berlin Heidelberg, p. 35–61.

Bider, I., Johannesson, P. and Perjons, E. (2013 b). Using Empirical Knowledge and Studies in the Frame of Design Science Research. To appear in Proceedings of DESRIST 2013, Lecture Notes in Computer Science, Springer Berlin Heidelberg.

Eekels, J. and Roozenburg, N. F. M. (1991). A methodological comparison of the structures of scientific research and engineering design: their similarities and differences. Design Studies, 12 (4), p.197–203.
Fischer, C. and Gregor, S. (2011). Forms of Reasoning in the Design Science Research Process. In: Jain, H., Sinha, A. and Vitharana, P. (eds.), Service-Oriented Perspectives in Design Science Research, Lecture Notes in Computer Science, 6629, Springer Berlin / Heidelberg, p.17–31.
Goldkuhl, G. (2011). The research practice of practice research : theorizing and situational inquiry. Systems, Signs & Actions, 5 (1), p. 7–29.
Goldkuhl, G. (2012). From Action Research to Practice Research. Australasian Journal of Information Systems, 17 (2).
Gregor, S. and Baskerville, R. (2012). The fusion of design science and social science research. *Information Systems Foundation Workshop*, Canberra, Australia, 13-14 Sept.
Hevner, A.R., March, S.T., and, Park, J. (2004). Design Science in Information Systems Research. *MIS Quarterly*, Vol. 28(1), pp. 75–105.
Johannesson, P. and Perjons, E. (2012). A Design Science Primer. CreateSpace Independent Publishing Platform.
Järvinen P (2007) Action research is similar to design science, *Quality & Quantity*, Vol 41, p 37–54
March, S. T. and Smith, G. F. (1995). Design and natural science research on information technology. Decision Support Systems, 15 (4), p. 251–266.
Oates, B. J. (2005). Researching Information Systems and Computing. 1st ed. SAGE Publications Ltd.
Österle, H., Becker, J., Frank, U., Hess, T., Karagiannis, D., Krcmar, H., Loos, P., Mertens, P., Oberweis, A. and Sinz, E. J. (2010). Memorandum on design-oriented information systems research. European Journal of Information Systems, 20 (1), p. 7–10.
Peffers, K., Tuunanen, T., Rothenberger, M. A. and Chatterjee, S. (2007). A Design Science Research Methodology for Information Systems Research. Journal of Management Information Systems, 24 (3), p. 45–77.
Salisbury Forum Group(2011). The Salisbury Statement. Social Work & Society, 9 (1), p. 4–9.
Sein, M., Henfridsson, O., Purao, S., Rossi, M. and Lindgren, R. (2011). Action Design Research. Management Information Systems Quarterly, 35 (1), p. 37–56.
Sutton, R. I. and Staw, B. M. (1995). What Theory is Not. Administrative Science Quarterly, 40 (3), p. 371–384.
Vaishnavi and Kuechler (2004). Design research in information systems. Retrieved (2013-04-12) from http://start.aisnet.org/?page=DesignResearchMethod&hhSearchTerms=design+and+research
Wittgenstein, L. (1973). Philosophical Investigations. 3rd ed. Pearson.
Wittgenstein, L. (1965). The Blue and Brown Books. 1st Edition in this form. Harper Torchbooks.