Design science for Small Scale Studies: Recommendations for Undergraduates and Junior Researchers

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Abstract: Design science is a research methodology that can be applied for both small scale studies at undergraduate level and for large scale application in the industry. Design science is a research methodology with several branches, with slightly different processes built around a common foundation. This paper has a focus on the branch developed by Johannesson and Perjons, and the five-phase model that is included in this branch: 1) explicate problem, 2) define requirements, 3) design and develop artefact, 4) demonstrate artefact, and 5) evaluate artefact. All these five phases must of course be carried out in a complete large-scale project in many real-world developments. However, the problem with applying a design science research project for undergraduates is that a thorough implementation of all the five phases is often too demanding for a Bachelor's or a Master's thesis. A reason for this is that several of the phases are better carried out in an iterative manner to obtain a quality result, which is time-consuming. The aim of this paper is to discuss the challenges and opportunities in applying design science for small scale studies, such as those conducted by undergraduates in their theses or by researchers new to the field. Based on this discussion, the paper concludes with a set of recommendations for how the design science methodology can be modified and applied to accommodate these smaller studies. The main recommendation is, as the principle for quality research, to delimit and to choose a specific focus that is carried out in depth. Some examples of focuses, that also are recommended by Johannesson and Perjons, are requirements and development focused design science research or evaluation focused design science research. An interesting follow-up to this position paper would be to study the application of design science in Bachelor's theses and where the emphasis is placed? Moreover, it would be interesting to investigate how design science is applied by researchers and compare if their emphasis in the design science methodology differs from that of undergraduates.

Keywords: Design science, Research methodology, Small-scale studies, Bachelor's theses, Master's theses

1. Introduction

Design science is a frequently used research methodology in engineering, computer science, information systems, or other fields where a research project aims at developing or using an artefact (Au, 2001; Gregor & Hevner, 2013; Wieringa, 2014). Design science research (DSR) has been defined as the scientific study of and creation of artefacts to solve real-world problems that are of common interest (Johannesson & Perjons, 2014). Seen as a research strategy, DSR resembles Action research in the sense that the outcomes of a study should solve an identified problem and improve existing processes. While Action research more directly addresses identified problems, DSR tries to solve problems by developing artefacts. In Action research, researchers are always involved in the investigated context, which not necessarily is the case in DSR. A strength with DSR is that it could be used both for small scale studies at undergraduate level in academia, and in large scale projects in the industry. DSR for computer science and information systems have several branches (Hevner et al., 2004; Peffers et al., 2007; Johannesson & Perjons, 2014), which have slightly different outlined processes, but are built around a common foundation. What is fundamental, and what the different branches have in common, is the idea of generating knowledge from gathering requirements, designing, developing, demonstrating, and evaluating an artefact.

This paper has chosen the branch of DSR developed by Johannesson and Perjons (2014), and to focus on how this research strategy or research framework could be applied in undergraduate projects in academia. The five-phase process that was outlined by Johannesson and Perjons (2014) is divided into the five phases of 1) explicating the problem, 2) defining requirements, 3) designing and developing an artefact, 4) demonstrating the artefact, and finally 5) evaluating the artefact (Figure 1). To obtain high-quality result in large scale projects these phases should be carried out iteratively with an incrementally improved outcome. The underlying problem, supported by the authors' experiences as researchers and higher education teachers, that motivates this study is that an iterative completion of all the five phases would be too time consuming for undergraduate projects, especially if a full-fledged artefact is developed and iteratively tested.

The aim of this position paper is to discuss the challenges and opportunities in applying design science for small scale studies, such as those conducted by undergraduates in their Bachelors' and Masters' theses or by

researchers new to the field. Based on this discussion, the paper concludes with a set of recommendations for how the design science methodology can be modified and applied to accommodate these smaller studies.

2. Design science

Design science has its roots in engineering and architecture and can be traced back to at least 1957 with the seminal work of Robert Buckminster Fuller. He was among many other things an architect, a systems theorist, a writer, a designer, and an inventor. The fundamental idea from Fuller that still is a core concept in DSR is to use scientific methods to solve human problems (Fuller, 1957). Another origin of DSR could be found in Simon (1969), even if the computer scientist and psychologist Herbert A. Simon presented his ideas as 'Design of Science' rather than Design Science (Huppatz, 2015). Simon's idea of 'The science of the artificial' moves the concept closer to the fields of computer science, software development and information systems that is the focus of this study. As pointed out by Baskerville (2008), there is no exact definition of Design science or DSR, and an explaining attempt could be, as done by Baskerville, to describe what Design science is not. On one hand DSR has been presented as a research paradigm (Hevner et al., 2004), on the other DSR has been posited as a research strategy like experiments and case studies (Oates, 2005).

Another way of outlining DSR is to use the Wittgensteinian idea of defining a phenomenon by its family resemblance (Johannesson, Perjons & Bider, 2013). The four suggested siblings in the article are 1) Branch of science, 2) Research strategy, 3) Practice research, and 4) Scientific method. Firstly, to compare Design science with Natural science as suggested by March, and Smith (1995), might be like comparing apples to blueberries. It seems to make more sense to compare Design science with Behavioural science as done by Hevner et al. (2004). Secondly, to claim a siblingship with research strategies is logical, and there are many studies that use DSR as the overall approach to answer a specific research question. Moreover, there are several similarities between DSR, Case studies and Action research that also might involve artefacts. Thirdly, the practical aspect of DSR seems rather obvious since a core principle is, like in Action research, to solve practical real-world problems. Finally, to classify DSR as a scientific method makes sense since DSR studies involve testing, observations, experiments, and other forms of systematic data collection to answer a research question.

Through the years DSR has developed and been refined into several branches (Hevner et al., 2004; Peffers et al., 2007; Kuechler & Vaishnavi, 2008; Johannesson & Perjons, 2014), that the authors all find useful for research in computer science and information systems. This paper is based upon the branch developed by Johannesson and Perjons (2014), created with the intention to support both graduate students and senior researchers to structure, conduct and present design science work. A research strategy, practical research method, or meta-framework that involves the five phases in Johannesson and Perjons (2014) design science are depicted in Figure 1 below.

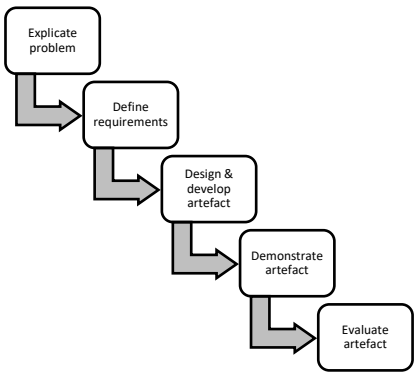

Figure 1: Summary of Johannesson and Perjons (2014) five phases in design science

3. Opportunities

Compared to other paradigms in research, design science develops or designs new artefacts (Venable, Pries-Heje & Baskerville, 2016). An important aspect of this is the practical contribution of design science studies and that the artefacts are often created to solve identified problems and improve the environment (Hevner et al., 2004; Hevner, 2007). Some contributions that design science studies can make are: artefact development can highlight need for new human activities, artefact development can make improvements to existing solutions, and design science can identify new uses for artefacts that already exists (Johannesson & Perjons, 2014).

A key activity to design science, next to that of development, is artefact evaluation (Peffers et al., 2012; Venable, Pries-Heje & Baskerville, 2016). Although design science is not the only research approach interested in evaluation (Hevner et al., 2004), its' connection to artefact development makes evaluation especially relevant for design science studies (Venable, Pries-Heje & Baskerville, 2016). The evaluation part of design science can also be an opportunity since it allows for identifying further improvements that can be carried out in artefact developments and study design (Johannesson & Perjons, 2014).

4. Challenges

Previous research has noted that design science can be demanding to conduct. For example, evaluation of the artefact that has been designed should be rigorous to demonstrate quality, efficiency, and functionality (Hevner et al., 2004; Venable, Pries-Heje & Baskerville, 2016). Further, artefact development can be demanding, where it can be difficult to determine the boundaries of the artefact (Johannesson & Perjons, 2014). Johannesson and Perjons (2014) also state that all studies carried out with the design science approach does not need to include all phases of design science and that some of the phases can be more in focus.

A common recommendation for design science is to apply an iterative research process (Hevner, 2007; Venable, Pries-Heje & Baskerville, 2016). The framework suggested by Johannesson and Perjons (2014) may resemble a waterfall model, but each phase may include several iterations. The expectation of including several phases in a design science study and carrying these out in an iterative process may contribute to the approach being perceived as demanding for small scale projects.

5. Discussion and recommendations

To work iteratively is today the dominating standard mode for development processes, even if some specific artefacts could need a waterfall like approach or a hybrid approach. As previously highlighted, although design science is often (and should when possible be) carried out with all phases of design science and in an iterative process, this is not always necessary or possible. Johannesson and Perjons (2014) have stated that research studies can focus on different phases of design science and that the phases can be carried out iterative or non-iterative. For small scale undergraduate DSR projects the overall recommendation is to choose, and focus on, a part of the five-phase process depicted in Figure 1. With the idea that a study with a narrower focus, conducted in more iterations, would have a more valuable output than the opposite. In this section, the authors discuss 4 recommendations for carrying out small scale design science studies.

5.1 Recommendation #1

Perhaps the most obvious approach to reduce the workload of a design science project is to limit the iterative process. This approach would resemble a waterfall model (Figure 2). Johannesson and Perjons (2014) have also stated that the phases of design science research can be carried out both iterative and non-iterative. However, for small scale studies, such as Bachelor's theses, this approach could still be perceived as too demanding. As highlighted in previous research, developing (Johannesson & Perjons, 2014) and evaluating (Hevner et al., 2004; Venable, Pries-Heje & Baskerville, 2016) the artefact should be rigorously conducted.

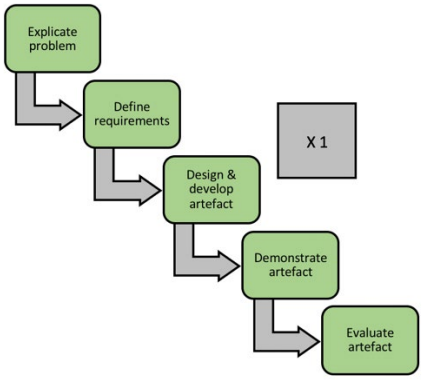

Figure 2: Non-iterative design science

If this approach to design science research is conducted in a small-scale project, the authors' recommendation is to have a clearly defined plan for the research project. This plan should preferably have a well-defined and

narrowed problem to explicate that suits a non-iterative and waterfall-like approach. Although this process would be non-iterative, it is still important that the study highlight needs in future iterations, for example in the discussion section or as suggestions for future research.

5.2 Recommendation #2

Another approach for a small-scale design science study would be to focus on the initial phases (Figure 3). Johannesson and Perjons (2014) notes that it is possible to perform both problem-focused and requirements-focused design science studies, where the problem or the requirements are carefully and rigorously examined. This approach would also exclude the more demanding parts of developing (Johannesson & Perjons, 2014) and evaluating (Hevner et al., 2004; Venable, Pries-Heje & Baskerville, 2016) an artefact. However, it should be noted that the phases of developing and evaluating artefacts are often considered key activities in design science (Peffers et al., 2012; Venable, Pries-Heje & Baskerville, 2016). To remove these phases from a research project, also small scale, would potentially call into question if 'Design science' is still an appropriate label for the study.

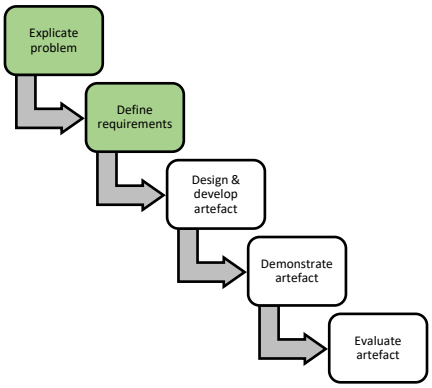

Figure 3: Problem and requirements-focused design science

If this approach to design science research is conducted in a small-scale project, the authors' recommendation is to clearly emphasize the need for future research in the discussion and/or conclusion section. The study should preferably also clearly connect the findings of the study to potential future design, development, and evaluation of artefacts. This could, for example, include a suggestion for future design. A study with this approach does not necessarily has to be labelled as 'Design science' but could instead describe itself as inspired by the design science approach.

5.3 Recommendation #3

Yet another approach for a small-scale design science study would be to instead focus on the last phases (Figure 4), with emphasis on the design phase. Johannesson and Perjons (2014) notes that design science studies with focus on development and evaluation is also a possible approach. These studies typically start with an existing specification of requirements for the artefact (Johannesson & Perjons, 2014). A strength with this approach, compared to the problem and requirements-focused approach (Figure 3), is the focus on design, development and evaluation that is often considered key activities in design science (Peffers et al., 2012; Venable, Pries-Heje & Baskerville, 2016).

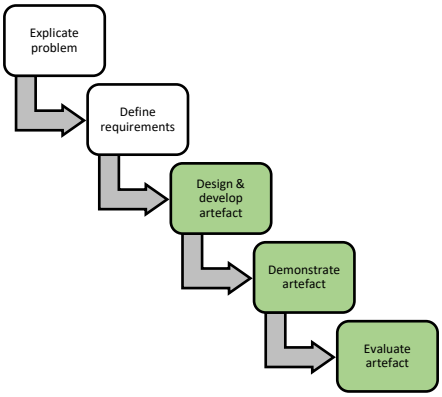

Figure 4. Design-focused design science

If this approach to design science research is conducted in a small-scale project, the authors' recommendation is to clearly state the connections between previous research (for example in the form of problem to explicate and requirements for the artefact) and the design, development and evaluation conducted in the study. This should preferably be discussed in the discussion section of a paper. A non-iterative small-scale study with this approach could further describe potential needs in future iterations, as suggestions for future research. It is also possible that the evaluation of the artefact highlights new problems or requirements that could be the endeavour for future research, which should then also be described.

5.4 Recommendation #4

Lastly, it is possible to focus on the very last phases of design science: demonstration and evaluation (Figure 5). Johannesson and Perjons (2014) highlights that some design science studies focus on the evaluation and that no new artefact is developed. This would address the challenge of design science being too demanding for small scale studies since the development part, which has been noted as one of the more demanding phases, has been cut from the project. Similar to the problem and requirements-focused approach (Figure 2), this approach could be questioned whether it is design science or not. This notion is also raised by Johannesson and Perjons (2014). However, compared to the problem and requirements-focused approach, this approach still carry out artefact evaluation which is often considered one of the key activities in design science (Peffers et al., 2012; Venable, Pries-Heje & Baskerville, 2016).

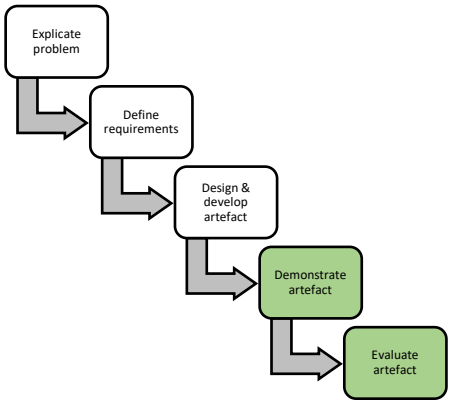

Figure 5: Evaluation-focused design science

If this approach to design science research is conducted in a small-scale project, the authors' recommendation is to clearly relate the evaluation of the artefact to future needs or re-design of the artefact, to not lose track of the 'science' in design science. This could for example be carried out critically and be used to identifying future problems and requirements, that could be investigated in future design science studies. In that sense, an evaluation-focused design science study could act as a pilot study for a more rigours and design-focused design science study in the future.

6. Conclusion

The conclusion of this position paper is that all the five phases of design science with an iterative research process are too challenging for a Bachelor's thesis, and probably for a Master's thesis as well. However, there are some potential exceptions from this. For example, theses conducted and authored by a pair of students and projects with a pre-stated and narrowed research plan, for example in collaboration with a company. In the instances where a full design science approach is deemed too challenging, it would be beneficial for both students and supervisors to choose some specific phases of the design science model to focus on. Moreover, the selected specific phases could preferable be carried out iteratively to optimize the outcome, and to relate and discuss those findings to the other phases of the design science model. This would be a good pre-training for the undergraduate students for future projects, both as a PhD student in academia or as employed in the industry.

7. Future research

An interesting next step of research would be to study the application of the design science methodology in Bachelor's theses and how the different phases were carried out. Where were the emphases placed? How many

iterations were carried out? Yet another interesting investigation would be to compare how design science is applied and described in research papers by researchers, and in theses by undergraduates. Furthermore, authors should, in a small-scale research project, split the work into fractions of the five-phase framework (Figure 1) to assess the strengths of carrying out DSR iteratively and incrementally.

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