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Design Thinking and Design Science Research

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Design thinking as an emerging trend in research and professional practice.

As a method of designing, design thinking focuses on the human-centered creation and evaluation of tangible artifacts. The result is a series of physical prototypes, such as new hardware gadgets, user interfaces, and mobile applications. Classically design thinking solutions aim to satisfy human needs. In addition it incorporates technical as well as business factors, which allow clients to make a production or deployment decision. The way designers solve problems is of value for both, research and professional practice.[1] Hence, the importance of design thinking lies in its power as a driver for innovation. In recent years, design thinking has spread to many domains beyond the borders of design.[2] Design thinking is currently applied in a wide range of contexts such as research, business, IT, innovation and education. The awareness level mostly stems from the management sphere and the extensive promotion by design agencies (e.g. IDEO).

Design science research on the other hand provides clear, consistent definitions and guidelines for the research process. The defining feature of design science research lies within the construction of new and innovative artifacts that solve relevant design problems.[3] It refers to an organized and systematic approach for the use of the knowledge base and the design environment to execute high quality design science research projects. Design science research builds on a wide range of shared methods either quantitative or qualitative in nature. This in addition to the availability of clear research guidelines has led to an extensive acceptance within the IS community.

During our research, we discovered an apparent resemblance between design thinking and characteristics of design science research as a research paradigm. The research goal of this whitepaper is to analyze the similarities and differences between these two approaches and to outline a framework for the extension of design science research by design thinking.

Is there a common understanding of design thinking?

Design thinking is about the way designers think and solve complex problems. The underlying assumption is that there are forms of knowledge special to the ability and capabilities of a

[1] Cf. (Leifer & Steinert, 2011).
[2] Cf. (Kimbell, 2011).
[3] Cf. (Hevner et al., 2004; Peffers et al., 2007).

designer.[4] The concept of design thinking is not new. Developed and applied as a method of engineering sciences, design thinking originated from Stanford University. At Stanford University design thinking is taught in a course setting in which students work on real world design challenges given to them by corporate partners. This concept of teaching can be found in several academic institutions and design schools around the world.

The term design thinking, originally coined by (Rowe, 1991), is applied and used in a wide range of contexts. Coexisting are different definitions of design thinking, since they are rooted in diverse perspectives:

- **Architecture**: The book "Design Thinking" by the architect (Rowe, 1991) was one of the first to illustrate the systematic use of problem solving procedures in architecture and urban planning. The main research focus lies within the domain of design cognition.[5]
- **Education**: Sometimes referred to as "design-based learning"[6], design thinking is seen as a model for enhancing creativity, endurance, engagement and innovation.
- **Industrial Design**: The focus of design thinking in industrial design lies within the act or process of designing as well as the designed end products.
- **Industrial Engineering**: Industrial Engineering aims to generate alterative solutions to satisfy performance requirements. In general, it focuses on the creation of new and innovative products.
- **Information Systems**: Within the field of information systems, the importance of design thinking is seen in its capacity to deal with complexity and its iterative process of design evaluation.
- **Innovation Management**: Here, the importance of design thinking lies within its power to foster innovation and to generate competitive advantages. It is used for product, service, and business model innovation.

Aiming to clarify the nature of design thinking in education and professional practice, an established framework for literature review by (Brocke, Simons, Niehaves, & Reimer, 2009) is used. Table 1 shows an extract of selected definitions of design thinking in literature over time. The assortment is based on relevance and citation frequency.

[4] Cf. (Badke-Schaub, Roozenburg, & Cardoso, 2012; Brown, 2008; Cross, 1982; Kimbell, 2011).
[5] Q.v. (Lawson Bryan, 2006).
[6] Cf. (Dym, Agogino, Eris, Frey, & Leifer, 2005).

Year	Author(s)	Definition: Design thinking	Publication Type
1982	Cross	*"(...) tackles **ill-defined problems**."*	Journal Article
2005	Dym et al.	*"(...) a systematic, intelligent process in which designers generate, evaluate, and specify **concepts** for devices, systems, or processes whose form and function achieve **clients' objectives** or **users' needs** while **satisfying** a specified **set of constraints**."*	Journal Article
2006	Dorst	*"This description of paradoxical situations defines the nature of the problematic relationship that designers and engineers are dealing with through **their design thinking**."*	Journal Article
2007	Junginger	*"(...) inquire into the organization's problems from an user's point of view."*	Practitioner Literature
2008	Bousbaci	*"(...) the study of the **cognitive processes** that are manifested in **design action**."*	Journal Article
2009	Brown	*"Design thinking begins with **skills designers** have learned over many decades in their quest to match **human needs** with available **technical resources** within the **practical constraints** of business. By integrating what is desirable from a human point of view with what is **technologically feasible** and **economically viable** (...). Design Thinking taps into capacities (...) that are overlooked by more conventional problem-solving practices. It is not only **human-centered**; it is deeply human in and of itself. (...) I now use it as a way of describing a **set of principles** that can be applied by **diverse people** to a **wide range of problems**."*	Book
2009	Martin	*"The design-thinking organization applies the designer's most crucial tool to the problems of business. That tool is **abductive reasoning**."*	Book

Table 1: Selective overview of relevant definitions for the term "design thinking".

For the conceptualization of the topic and the deduction of a classification recurring keywords from the definitions for design thinking are highlighted (see Table 1). In general, the term "design thinking" is used too loosely. Apparent is the dichotomy between scientific rigor and the relevance for professional practice. The understanding in literature suggests three

domains of design thinking:[7]

1) Design thinking as a cognitive style.
2) Design thinking as an embedded principle in professional practice.
3) Design thinking as a method to guide the process of designing.

Common characteristics identified in the literature on design thinking are its' human-centeredness, the notion of lateral thinking, the use of distinctive tools and methods, and the design problem to be wicked or ill-defined in nature.[8]

> Accordingly, we define *design thinking as an approach to foster the process of designing through an iterative process of human-centered idea generation and evaluation in a team context.*

The application of design thinking as a method in practice starts approaching a problem from a human perspective. With the primary focus on people and their needs, it integrates human, business, and technical factors in problem identification, solution, and design.[9]

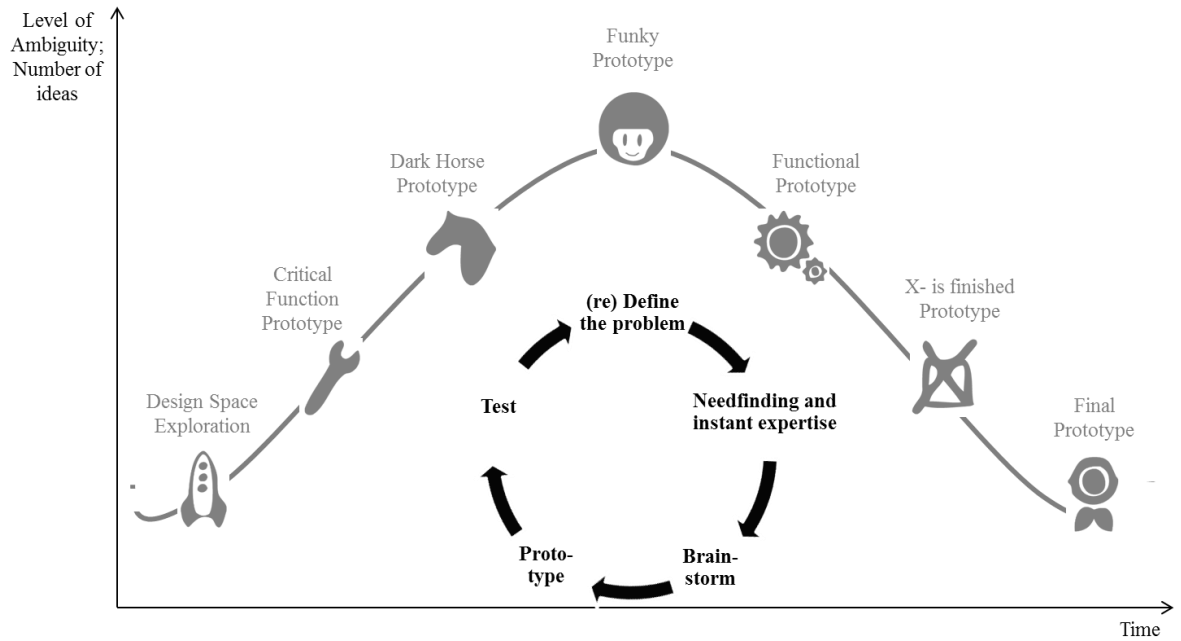

Figure 1: Design thinking iterative solution search processes.[10]

[7] Cf. (Clark & Smith, 2010; Kimbell, 2011; Lindberg, Meinel, & Wagner, 2011).
[8] Cf. (Buchanan, 1992; Cross, 1982; Dorst, 2012; Lawson Bryan, 2006; Martin, 2010).
[9] Cf. (Bousbaci, 2008; Cross, 1982; Dorst, 2012; Leifer & Steinert, 2011).
[10] Adopted from (Plattner, Meinel, & Leifer, 2010).

The creation and evaluation process of an artifact follows an iterative solution search process. In the following, we use the solution search process micro-cycle as utilized at Stanford University and the University of St. Gallen: re(define) the problem, needfinding and instant expertise, brainstorm, prototype, and test. Overall, the iteration cycle additionally follows a clear structure of different macro process phases (see Figure 1). This enables a content-related design cycle fostering diverging and converging stages within the process of designing.

Towards an extension of design science research.

Design science research provides clear, consistent guidelines for conducting, evaluating, and presenting good, qualitative design science research. "It is the synergy between relevance and rigor (…) that define good design science research."[11] Following these definitions of design science research by (Hevner, March, Park, & Ram, 2004; Hevner, 2007; Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007), Table 2 visualizes the common ground and potential areas for rapprochement between the design science paradigm and design thinking. The mapping is based on our understanding of the method of design thinking, which is deduced from research relating to the systematic analysis of 32 design thinking projects conducted at the University of St. Gallen between 2005 and 2013.

A common characteristic within the analysis of design science research and design thinking is the nature of the design problem solved. Both paradigms address either important, yet unsolved problems in an innovative way, or solved problems in a more efficient way (G2; A1). The overall objective is usefulness of the designed artifact. Whereas the focus of design science research lies within solving an important business problem, design thinking identifies problem relevance via human-centered needfinding (G1). The approach of artifact design and evaluation in the form of an iterative process are the same for design science research and design thinking (G3; G6). They rely on creativity and trial-and-error search. User testing is an integral part of the design thinking micro-cycle. The specific activities for evaluation are assumed to occur ex post, i.e. after the construction of an artifact (G3; A5). The process of problem-solving follows a rather specific sequence of activities that in consequence produces the final design output (G1; G2).

[11] (Hevner, 2007).

DSR Guidelines	Description of DSR Guidelines	Assessment: design thinking – design science research
G1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.	✓ Result: creation of a purposeful artifact, which addresses an important (organizational) problem. ✓ Form of the artifact: instantiations and models. × Designed artifact solves a more specific, identified problem, rather than a generic class of problems.
G2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.	✓ Objective: construction of new and innovative prototypes aimed at satisfying human needs.
G3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.	✓ Evaluation of designed artifacts using observational, experimental, and descriptive methods as well as testing. ✓ Evaluation phase to provide essential feedback for the construction of an artifact. × Lack of rigor, in terms of reliability and validity of the design evaluation process.
G4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.	✓ Design artifact may extend the knowledge base or apply existing knowledge in new and innovative ways. (✓) The creation of an artifact may extend and improve the knowledge base foundations. × The creation of an artifact scarcely provides precise and implementable additions to the evaluation methodologies.
G5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.	✓ Artifacts are built and evaluated within an appropriate use of the knowledge base. × No rigorous assessment with respect to the applicability and generalizability of the designed artifact.
G6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.	✓ Problem-solving as an iterative solution search process. ✓ Effectiveness in terms of the search for satisfactory solutions.
G7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.	✓ Sufficient communication of the artifact's use within the organizational context.

Table 2: Assessment of design thinking using the guidelines for design science research.[12]

[12] Cf. (Hevner et al., 2004; Peffers et al., 2007).

Evaluation (A5) of the artifacts created determines whether additional iterations are needed. "This activity involves comparing the objectives of a solution to actual observed results from use of the artifact in the demonstration."[13] In general, design science research evaluations focus on an artifact's usefulness in terms of the descriptive knowledge about the artifact. Hence, the evaluation of an artifact's design, such as its rationale and specifications, are underrepresented in design science research (G1; G2; A5). Additionally, in design science research only descriptive knowledge on the usefulness of a design outcome in a specific context is perceived to be a theoretical contribution of rigor (G4; G5; A6). However, design decisions significantly impact the potential usefulness of an artifact, as the design artifacts emerge throughout the design process. Consequently, we perceive the method of design thinking to be of additional value to the process of designing.

An analysis of the seven activities of the design science research methodology (DSRM) process according to (Peffers et al., 2007) is included in Table 3. The DSRM process allows for different research entry approaches within the nominal sequence (A0). Hence, the process of designing can commence at A1, A2, A3, or A4, depending on the kind of entry point chosen. This choice may result in a research process, which converges towards the creation and adaption of a limited set of pre-defined artifacts.

In contrast, the process of design thinking includes a constant, iterative cycle of problem identification and (re-) definition.[14] This allows for diverging and converging phases within the artifact design process. Additionally, the embedded layer of meta-processes that is unique to the method of design thinking supports a rather comprising, content-related exploration of design alternatives. The design science research process, on the other hand, sees process iteration only within the defining objectives of a specific solution (G6; A7).[15] This posits a limitation onto the problem as well as the solution space within the design science research paradigm.

Having analyzed the similarities, differences, and potential areas of application between these two approaches, we argue for an extension of design science research through design thinking and vice versa. Considering design thinking to be one method of design science research allows for purposeful and value-creating additions to the execution of design science research project.

[13] (Peffers et al., 2007), p. 56.
[14] Cf. (Akin & Lin, 1995).
[15] Cf. (Peffers et al., 2007).

DSRM Process Model	Description of DSRM Activities	Assessment: design thinking – design science research
A0: Possible research entry point	Possible research entry point are problem-centered initiation, objective-centered solution, design-and-development centered initiation, and client/context initiation allowing for different points of entry within the nominal process sequence.	✓ Starting point of the design thinking process is a problem-centered initiation. × Design thinking doesn't allow for diverse research entry points. The design thinking cycle always starts with the activity of problem identification and (re-)definition.
A1: Identify Problem and Motivate	Define the specific research problem and justify the value of the solution.	✓ Ensuring importance and problem relevance through focus on satisfying human needs.
A2: Define Objectives of a Solution	Infer the objectives of a solution from the problem definition and knowledge of what is possible and feasible.	✓ Description and demonstration of how a new artifact is expected to solve an unsolved problem or a solved problem in a more efficient way. ✓ Evaluation of objectives through benchmarking of the artifact. ✓ Inference of human (desirability, usability), technical (feasibility), and business factors (viability) in problem identification, solution, and design.
A3: Design and Development	Create the artifact.	✓ Building of new and innovative artifacts as prototypes. ✓ Form of the artifact: instantiations and models.
A4: Demonstration	Demonstrate the use of the artifact to solve one or more instances of the problem.	✓ Demonstration of designed artifacts using observational, experimental, and descriptive methods as well as testing.
A5: Evaluation	Observe and measure how well the artifact supports a solution to a problem.	✓ Evaluation of designed artifacts using observational, experimental, and descriptive methods as well as user testing. × Lack of rigor, in terms of reliability and validity of the design evaluation process.
A6: Communication	Communicate the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences.	✓ Sufficient communication of the artifact's use within the organizational context. × No rigorous assessment with respect to the applicability and generalizability of the designed artifact.
A7: Process Iteration (A5/A6 → A2/A3)	The process is structured in a nominally sequential order. At the end of A5 and A 6 researchers can decide whether to iterate back to A2 or A3 to improve the effectiveness of the artifact.	✓ Problem-solving as an iterative solution search process. ✓ Constant, iterative cycle of problem identification and (re-) definition. × Iteration includes the whole process of designing, always starting with the first activity within the micro-cycle "(re-) define the problem". × Content of iterative cycle is pre-defined by the embedded macro-cycle of design thinking.

Table 3: Assessment of design thinking using the DSRM process model.[16]

[16] Cf. (Peffers et al., 2007).

Limitations and areas for future research.

Using a common frame to analyze the similarities and differences between design science research and design thinking, we assessed the method of design thinking to the design science research paradigm. In general, we propose the use of design thinking as a method to guide qualitative design science research, in terms of the creation and the evaluation of desired artifacts. In summary, the contribution of design thinking is seen in the domains human-centeredness, the divergent as well as convergent trial-and-error search processes, the use of distinctive tools to foster creativity, the tangibility of design artifacts, field testing, and the iterative solution search process. Currently, design thinking distinctively lacks in rigor as a research method. This is evident throughout the build-and-evaluate loop of design artifacts. Consequently there is a need to enhance the anticipation and rigorous assessment of the knowledge base as proposed by the design science research guidelines.

These findings provide guidance for future research endeavors, in particular the assessment, classification, and differentiation of design science research and design thinking. In addition, the presentation of design thinking and its relevance as applied in practice might be of interest. This involves the evaluation of design thinking projects along the guidelines and activities given by the design science research methodology. Drafting the role of design thinking as an established research method helps to improve its acceptance and encourages its adaptation in both, research and professional practice.

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