Enhancing Design Science through Empirical Knowledge: Framework and Application

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Abstract. The discourse about differences between behavioral and design science still attains wide interest in the information systems research community. While design-oriented research is repeatedly subject to criticism on account of lacking transparency and rigor, behavioral research is fighting against the accusation of little relevance. It would be highly desirable to overcome the shortcomings of design science by using existing theories, empirical knowledge, etc. within the design of an artifact. For that purpose, we present a framework that shows how different ways of applying empirical knowledge can put the research of design scientists on a better grounding and thus improve the rigor of design science. Specifically we point out, how design science can be performed more rigorously on the basis of our framework by empirically motivating, guiding, evaluating, and analyzing design science research. To illustrate the application of our framework, we will provide an example from the domain of information security.

Keywords: Design Theory, Empirical Knowledge, Framework.

1 Introduction

Regionally bound research traditions, diverse intellectual background, differences within the education of scholars of the field, etc. [1] are responsible for the different types of research results found in information systems research (ISR). Consequently various types of research results are generated due to different research paradigms, which are distinguished into a design-oriented (design science) and a behavioral (behavioral science) paradigm [2]. Design science research in information systems (DSRIS) is mainly concerned with the construction of IT artifacts[1] that are intended to solve relevant problems in an innovative way or optimize existing solutions for relevant problems and therefore belongs to design science [3]. Business & information systems engineering (BISE), as prevailing within the German-speaking domain is on of the biggest communities of design scientists [4]. In contrast, behavioral ISR, predominately located within the Anglo-American domain, deals with the development and justification of theories which explain and predict phenomena related to the use of information systems [2].

[1] IT artifacts are constructs, models, methods, and instances [2, 10].

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Because of that, varying types of research results can not only be traced back to the mentioned regionally bound research traditions, but also to different Denkstile (rooted in engineering vs. natural-science-oriented research approaches), which determine the application of diverse research methods or the respective research goals (truth vs. utility). Synergy effects and further potential, which could result from overcoming the borders of these paradigms, are hardly being realized [5]. But, some authors propose and call for a mutual exchange between design-oriented and behavioral research [1, 6]. This is regarded as being useful in the following ways: For one, empirical research results can trigger design-oriented research by offering insights into and pointing to interesting and relevant phenomena. Understanding the cause of and having the knowledge about problems related to studied phenomena could motivate design-oriented researchers to solve these problems with the means of innovative or improved IT artifacts [7, 8, 9].

Following this line of thought, decisions within the design process of IT artifacts could be more strongly linked to and grounded in theoretical knowledge or empirical evidence to account for more transparency and rigor within DSRIS [2, 4]. An alternative perspective is viewing IT artifacts as subjects of empirical research, e.g., in behavioral science. On the one hand, this would allow for a broader evaluation of the utility of the IT artifact [2, 10]. On the other hand, it would foster the production, evaluation and use of knowledge about the IT artifact [6].

In this paper we propose a framework to support a stronger collaboration or even integration of empirical research into DSRIS from a design science perspective. In doing so, we address the different ways of leveraging the benefits mentioned above. As our main contribution we distinguish between different types of application of empirical knowledge in design science and we outline how design science research can be improved by additional rigor in certain parts of the research process.

The remainder of this paper is structured as follows: First we will establish an essential terminology to fall back upon in the subsequent sections and to increase the transparency of our framework construction. In section 3.1 we will derive all important elements of our framework to explain their interplay in section 3.2. In section 4 we demonstrate the application of our framework with the aid of an example from information security research. Section 5 discusses our findings and in section 6 we provide concluding remarks and describe potential future research.

2 Basic Considerations and Related Work

In order to better understand the divide as well as potential points for collaboration between the two paradigms of research, it seems helpful to go back to the proverbial roots. By shedding the labels for a moment we strive for a new perspective on the paradigms and their divide. In this section we conceptualize ways of leveraging the synergy and potential between the two research paradigms by broadening our view to two of Aristotle's virtues of thought: episteme and techné. Additionally we derive what we consider approaches of design science which help us distinguishing between the scientific process in design science and design practice.

A first step is establishing what science and thus the scientific process is. In science we search for truth. The Greeks philosophers described the transition of *that* *which was believed to be true* (doxa) to *that which was known to be true* (episteme) as the scientific process [11]. Doxa and episteme can be considered as the two extremes of this spectrum of certainty in knowledge regarding its truth. Along with this dimension of truth, there is also the dichotomy of theory and practice. The Greek philosophers, especially Aristotle in his work Nicomachean Ethics [12], talk about episteme and techné. Episteme was considered scientific knowledge with the connotation of absolute certainty, which differs from our contemporary understanding and use of the term. An example used by Aristotle was the field of mathematics, especially geometry, where formal proofs can lead to absolute certainty about knowledge ("We are all convinced that what we know through episteme cannot be otherwise than it is", [12]). Such certainty is hard to find in nature and the question of how we can know something to be true led to a refined definition of knowledge, in which knowledge can only be asserted. By means of experimentation and (empirical) evidence, the knowledge we attempt to gain is "conceived in a probabilistic sense" [11]. By deploying the scientific process (i.e. moving further away from doxa, the mere belief in knowledge), we develop knowledge with a higher certainty of truth. In our contemporary understanding episteme are theories, which were hypotheses (doxa) until – through scientific methods – our certainty in the truth of this knowledge rose.

Another virtue of thought is techné, which describes practice and is often being translated as craft or art [13]. The actions of a practitioner are guided by another type of knowledge. Philosophy knows the term practical knowledge, which according to Aristotle – as a result of practical thinking – can also be true or falsify, but only in relation to the desire of the practice or action. A contemporary interpretation of the term desire in this context would be purpose. As such practice also holds a form of knowledge; however its truth or falsification can only be determined in relation to the purpose the practice had. This practical thinking however does not derive from theoretical thinking, but from means like trial & error. What deviates from episteme is the lack of a scientific process about techné in the writings of the Greek philosophers. The systematization of such knowledge and treatment with scientific methods is a research endeavor in the field of design science research for some time now. As such "…techné expresses a demand for a theoretical awareness which, so to speak, justifies conceptually that practical knowledge which is already established empirically. Techné consolidates this practical knowledge and affords it a certain extension – due to the inherent generality of theoretical knowledge – …" [14].

This consolidation has made major progress in the past. We explore opportunities from the design scientists' point of view by learning from and leaning on inform design science research. In order to do so the duality of design needs to be discussed. The word design can be both a noun and a verb (or i.e. a product or a process) [2]. Design as a noun is the proposition that a certain artifact (the result of design science), as a combination of its components, can generate the desired utility (serve its purpose), which is essentially knowledge in the uncertain state of doxa. Especially when developing an innovative artifact the outcome of a proposed design is not absolutely clear. Once the artifact is built, it can be evaluated in regard to whether or not it serves its purpose. Confirmation of the artifact doing so (e.g. by an empirical study) is a step towards a higher level of certainty about the initial proposition. Such explanations have been associated with terms like "design theory" or "explanatory design theory" [15]. This is one of the approaches in design science and is similar to the process of theory building with a delayed (due to the construction of the artifact) theory testing known from sciences which are assigned to the virtue episteme.

The other aspect is design as a verb or process. According to [15] a design practice theory would describe how the designer achieves his design goal and builds an artifact; an action also known as projection [16]. As such a potential design practice theory would structure and reason the projection of functional explanations from an explanatory design theory to the final artifact. However, the possibility of a design practice theory is part of an on-going discussion in the ISR community [17, 4].

Design science, as the "science of the artificial" [18] has the artifact at its core. From motivating the need for an artifact to its construction and concluding evaluation, the majority of activities in design science [2, 19] are centered on it. [10] explicate that behavioral science – as a form of natural science – investigates both natural and artificial phenomena. It seems helpful to use this distinction in regard to a science of the artificial in order to find opportunities to use or generate episteme and thus integrate both research paradigms tangibly. We will subsume sciences that investigate natural phenomena as reference theories about natural phenomena [20], indicating that ISR as a science discipline lends from the rich set of theories from other sciences, in absence of ISR kernel theories [10, 2]. Sciences that are linked to episteme (and as such generate scientific knowledge), but theorize about artificial phenomena are labeled reference theories about artificial phenomena. We consider this a third approach to theorizing design science research (along with explanatory design theory and design practice theory), which seems to be a recent development [20, 6].

In this section we showed the general distinction between episteme and techné, or their contemporary counterparts: theory and practice. We identified three approaches within design science research which attempt to theorize design science and help distinguish the scientific aspect from design practice. Building on this we will show means of motivating, guiding, evaluating and analyzing design science research with the help of scientific knowledge from the behavioral science in ISR and other sciences in order to improve the rigor of design science and help with a theoretical foundation of design science research activities.

3 Framework for Empirical Based Artifact Design

3.1 Essential Elements of the Framework

As a preliminary step, we derive four types of support for design science from the two so called 'useful ways of mutual exchange' mentioned in the introduction. The four types furthermore rest upon [2, 19]: Table 1 shows the relation between these four types of empirical support and the design science process model by [19]. This is done to convey how the research model integrates with the construction process of an artifact to increase the rigor of said process. Additionally the design science guidelines by [2] are linked to show where our framework makes a contribution to design science in general.

Table 1. Types of Application of Empirical Knowledge and their Relatation to [2, 19]

Types of Application of Empirical Knowledge		DS Process Model [19]	DS Guidelines [2]
1	Establish DS problems and motivate design empirically	Problem identification and motivation (activity 1)	Problem relevance (Guideline 2)
2	Support design decisions and design actions empirically	Define the objectives for a solution (activity 2); Design and development (activity 3)	Research rigor (Guideline 5)
3	Evaluate design result empirically	Evaluation (activity 5)	Design evaluation (Guideline 3)
4	Analyze design result empirically	n/a	Research contribution (Guideline 4)

Reference Theories of Natural Phenomena

The objective attributed to reference theories of natural phenomena is to „… explain how and why things are" [10]. Since these disciplines are developing insights into natural phenomena they consequentially do not generate knowledge about artifacts. From a design science perspective this kind of research can be labeled also non-artifact-centric research. The outputs of these research endeavors are empirically tested hypotheses, which ideally come attached with certain empirical evidence. Such insights into natural phenomena are of importance for design science, as design science researchers try to influence these by constructing an artificial object [21, 10] to e.g., emulate the cause of a desired phenomenon. From the design scientists' perspective, they can be regarded as reference theories [9, 10, 20] which explain and make predictions about natural phenomena [22]. Such explanatory and predictive theories are based on causes and effects [23].

The element 'cause' is in a directional relationship with the element 'effect', with both being parts of the element hypotheses (figure 1). From empirical testing of such hypotheses we gain a level of empirical evidence [24], which we earlier referred to as the level of certainty about knowledge to be true.

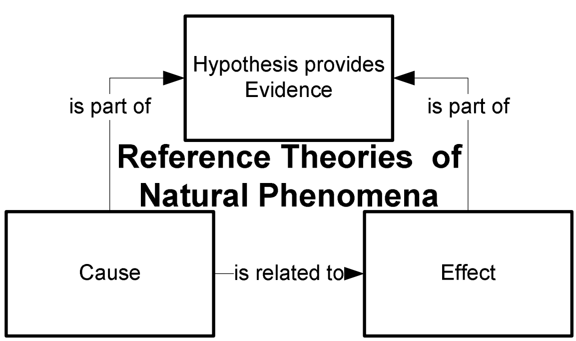

Fig. 1. Elements from Theories of Natural Phenomena

From a design science perspective this evidence about explanations or predictions of natural phenomena can be used to generate or improve requirements for the design, which allows grounding of the problem statement with empirical data [7, 8, 9, 18]. Furthermore this knowledge can be the motivator for the construction of the artifact to solve an existing problem (e.g., to address the lack of a cause for a desired effect).

Explanatory Design Theory

Design theories can be operationalized for the construction of an artifact [17]. In their work, [15] separate the theoretical component about design practice from the theoretical component about the design artifact. This is in accordance with the aforementioned duality of the design term. The explanatory design theory holds functional explanations about „…, why designs and artifacts have certain attributes and features“ [15] and calls for the decomposition of the design goal into concrete requirements, which have to be fulfilled by the components of the artifact (Figure 2). The design goal can be based on reference theories in order to motivate and reason the construction of the artifact based on empirical research.

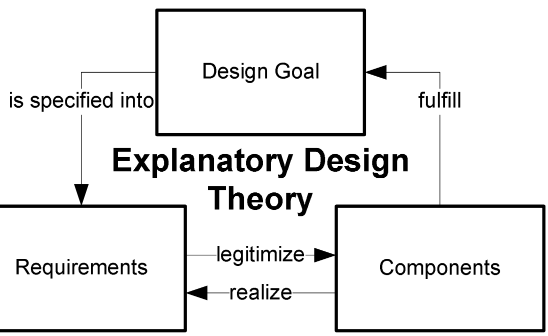

Fig. 2. Explanatory Design Theory according to [15]

Components are in a functional relationship with their requirements. „ The nature of the requirements explains the incomplete description in terms of the requirements.“ Additionally the components are being legitimated by the defined requirements [15]. The requirements derived from the design goal can be considered the ends of the design and the components the means. This way a means-ends-relation can be derived [7]. The explanatory design theory should ensure the internal cohesion and consistency of an artifact [25]. It can be interpreted as a blueprint which describes the requirements and components needed to fulfill these, but does not instantiate these component types.

Design Practice Theory

A design practice theory describes the practical way of „…how to design something“[15]. [23, 26] refers to theories for design and action and describes prescriptive technological rules, which state: „… if you want to achieve Y in situation Z, then perform action X“ [5]. This prescriptive procedural knowledge can for example be structured by a design method [9]. According to [27] such a design method is an (IT) artifact itself, which takes the form of a meta-design that needs to be instantiated for specific situations. To consider this aspect and avoid a too narrow interpretation of technological rule as a method, we're using the term design action (Figure 3).

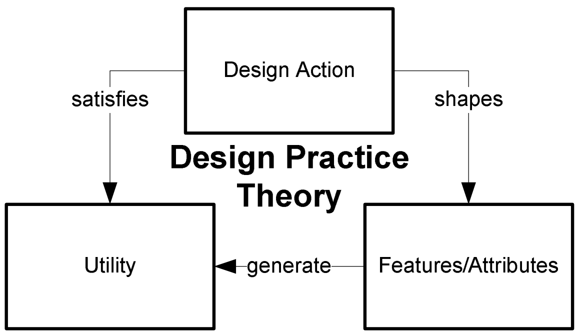

Fig. 3. Design Practice Theory

Design action configures the features and attributes of the components, which were defined earlier in the explanatory design theory. These configured components then generate utility (regarding the task of fulfilling the requirements). The element design action can be guided by episteme (in form of theoretical or empirical knowledge) in the configuration process of the components. By doing so, the design decisions and actions can be justified with empirical data which makes the design practice more rigorous as it becomes more transparent and well-reasoned.

Reference Theories of Artificial Phenomena

Along with natural phenomena also artificial phenomena exist [10, 18]. In principle research streams that focus on artificial phenomena follow the same processes as research does which theorizes about natural phenomena. As described in section 2 this kind of research deviates slightly. [20] describes it as additional features), because between doxa and episteme there is the construction of the artifact, which is the subject of the research. The aspect which [20] labels as "exterior mode of design disciplines which theorize about artifacts in use" is found also in [6] in the form of so called design knowledge. To emphasize the focus on the artificial in this kind of research, we subsume it under the label artifact-centric research.

In artifact-centric research the knowledge about an artifact (or artificial phenomenon) is gained by the use of scientific method to identify context-specific effects and side-effects of the artifact use or costs that arise from using the artifact for its intended purpose [6]. Artifacts that show similar means-ends-relations can be tested using comparative requirements [6], e.g. to determine what artifact generates highest utility in regard to the chosen requirements. Such a comparison can be based on various sets of features and attributes [20]. In contrast, the evaluation of the artifact is assigned to the design process of the artifact and determines the utility based on specific criteria [2, 19]. The artifact-centric research develops insights into features or attributes of the artifact, which can be transformed into technological rules, which then can support design decisions and design action [20]. Knowledge about the artifact is generated and the artifact is analyzed for both intended and unintended effects of its. Additionally such research can motivate the design of a new artifact or an improvement of an existing artifact based on its defects.

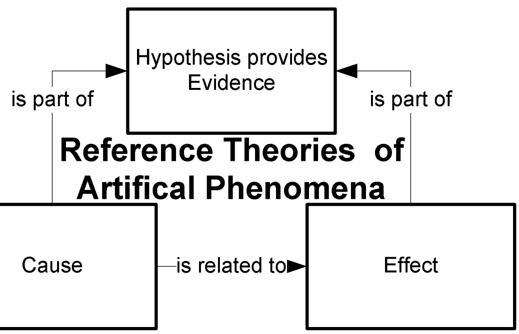

Fig. 4. Elements of Reference Theories of Artificial Phenomena

Figure 4 illustrates the elements and the similarity to the cause and effect relation found in reference theories of natural phenomena. However we substitute – or rather specify – the cause for the artificial phenomenon with the artifact to also show the subtle differences. We propose that theories about artifacts can be one research output of such endeavor.

3.2 Framework of Empirically Supported Design Science

In this section we will merge the quadrants, the four types of theories described above and their elements together what will result in our framework (figure 5). The framework is divided into two columns representing on the left side episteme and on the right side techné. In the upper left quadrant knowledge concerning natural phenomena is generated, which can be found consolidated as reference theories of natural phenomena. Knowledge concerning artificial phenomena, which is or can be found consolidated as reference theories of artificial phenomena, is located in the lower left quadrant. As show in figure 5 non-artifact-centric knowledge as well as artifact-centric knowledge is handed over to the entire right techné column. It is illustrated by the two depicted arrows, named non-artifact-centric and artifact-centric knowledge, as each of these arrows touches the entire column. In the upper right quadrant of the techné column the explanatory design theory is located which holds the functional explanation of the designed IT artifact. Straight under the explanatory design theory, the design practice theory has its position. The design practice theory supports shaping the attributes and features of the above defined components.

The resulting IT artifact, which is the final design product, has to be handed over from the techné column to the lower left quadrant in the episteme column. This particular transfer is restricted to the lower left quadrant as only there is knowledge generated concerning artificial phenomena. This is indicated by the arrow named artifact that touches solely the quadrant in the lower left corner.

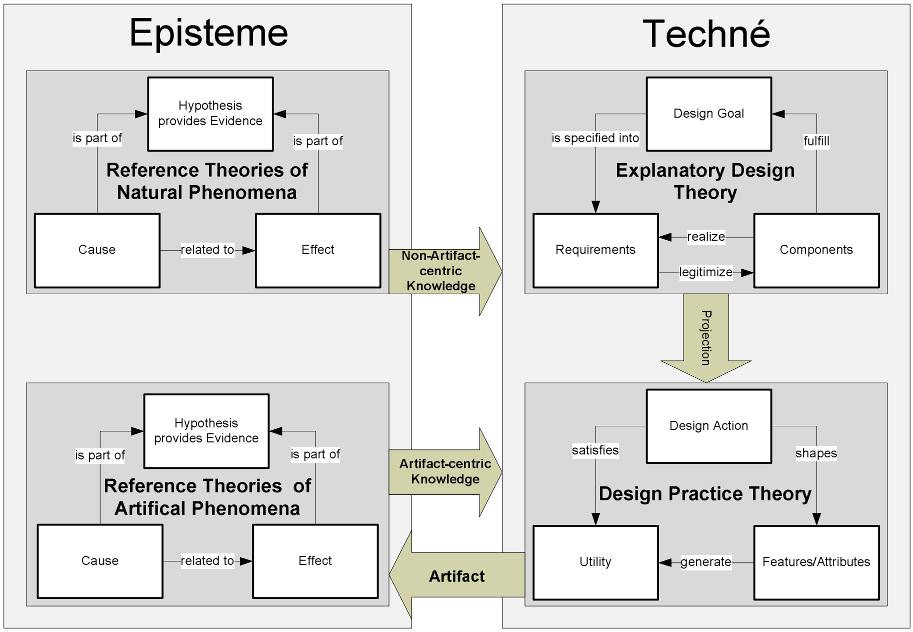

Fig. 5. Research Framework for Empirical-Driven Design Science (EDDS)

The following part of this section is reserved to explain the integration of empirical knowledge into design science. Therefore, we callback to our four types of application of empirical knowledge from table 1; these are explained by the means of our framework. Establishing the problem and motivating the design of an IT artifact can be supported by non-artifact-centric as well as by artifact-centric knowledge. In the first case, theoretical or empirical knowledge is taken from a reference discipline. This knowledge serves to establish the problem more rigorously and to motivate the design of an IT artifact solving the investigated problem. In the second case, an unintended side effect is discovered within the artifact-centric research that is caused by an IT artifact, for instance. Thus, this can also serve to establish and motivate a problem to be solved.

Both design decisions and actions can be supported by non-artifact-centric and artifact-centric knowledge stemming from the episteme column. Whereas design decisions are made at the level of the upper right corner, as the structure and the interplay of the components are defined related to the requirements derived from the design goal, within the design practice theory design actions are responsible shaping the features and attributes which are instances of the components. Artifact-centric and non-artifact-centric knowledge can be utilized for the definition of the requirements regarding the components. Similar holds true for the design practice theory, but in contrast from artifact-centric knowledge very concrete technological rules can be derived [20]. Technological rules can also be derived from non-artifact-centric knowledge. Anyway, the derivations of these technological rules have left some room for interpretation [5].

The evaluation of the design result, the IT artifact, is an intrinsic function of design science and therefore, takes place right after the design and development of the artifact. Noticeably, as mentioned before, artifact-centric research has to be distinguished from artifact evaluation, because it differing aims reach beyond an evaluation. Regarding the evaluation issue, there is a plethora of literature available in DSISR. Hence, we do not stress this topic in this paper and thus refer to relevant literature [2, 28, etc.]. Analyzing the design results is in the scope of artifact-centric research. The IT artifact resulting from the design practice can be transferred to the lower left quadrant as illustrated by an arrow in our framework in figure 5. Herein, new knowledge is generated about the artifact and from there about artificial phenomena. New and innovative knowledge about the artifact and its application domains can be analyzed whereby new knowledge and also new technological rules can be passed to the techné column.

4 Application of the Framework

To further illustrate the application of the framework we will give a brief example of how the framework can be applied to design science research which draws from empirical knowledge. This example from the information security domain will describe the design and development of a password policy. The aim is to collect empirical knowledge relevant to the design artifact and deduce from empirical findings (cause-and-effect relationships) guidance on 1) what needs to be considered (requirements), 2) how the artifact should be constructed (selection and configuration of components) and 3) what effects are to be expected from the application of the artifact (utility and side effects).

Table 2 lists empirical knowledge that is found in the left column of the framework (episteme). The last column shows where it can be applied in the design science process model suggested by [19]. Terms from our framework are underlined in the table. The table presents a small selection of research that may be relevant for the desired design artifact. Even with such a small set of empirical studies the importance of cause-and-effect-like relationships becomes clear to the design scientist and help structure findings which may have relevance to his design.

The study by [29] shows ill-effects of password policies which do not consider the users capabilities (like the ability to memorize passwords) and thus motivates the design of an artifact to consider or overcome these disadvantages. As such the requirements are constructed (or adjusted) in order to eliminate the cause (bad password minimum specifications), so the undesired effect (user coping mechanisms which endanger security) does not set in or is at least mitigated.

The knowledge that multiple passwords are a burden for users can lead to adjustments of the policy in regard to whether or not the user should be forced to have unique passwords for every system he has access to. Coupled with the knowledge that frequent password changes have a negative effect this can lead to the design decision, that users should only use one password (high memorability) with a moderate to low change frequency – which is balanced by stricter rules regarding the password strength. When formulating a policy the implied goal is that it will be followed, so the desired effect (utility of the artifact “password policy”) sets in.

Table 2. Impact of Episteme on the Design of a Password Policy

Source of Episteme	**Empirical Findings**	**Application of Empirical Knowledge**	**Impact on Techné**	**Design Process Step(s) [19]**
[29] (Reference theory from artificial phenomena)	Conflicts between policies and user capabilities Coping mechanisms of users endangers overall security	Motivating artifact construction (#1) Guiding design decision and action (#2)	Requirement: "Password rules must match user capabilities" Configure policy rule (component) to allow for long password lifetime before cycling.	Problem identification and motivation Define the objectives for a solution Design and development
[30] (Reference theory from artificial phenomena)	High level of perceived sanction severity increases user compliance with security policies	Guiding design decision and action (#2) Evaluate design result (#3)	Requirement: "Policy compliance" Configure the policy-component "Sanctions" to reflect high severity Utility: Consider costs of high sanction severity (e.g. recruitment costs if sanction is job termination)	Design and development Evaluation
[31] (Reference theory from natural phenomena)	Moral beliefs are a strong determinant of deviant behavior and work as a self-regulatory approach	Guiding design decision and action (#2)	Phrase the guidelines (component) in a way which appeals to moral beliefs	Design and development
[32] (Reference theory from artificial phenomena)	Educating users on password selection methods improves password quality Random passwords are harder to remember than other types	Guiding design decision and action (#2)	Requirement: "Policy should also educate users" Add mnemonic passwords and pass phrases as recommendations in the component "Guidelines"	Define objectives for a solution Design and development

With the knowledge from the work of [30] such compliance can be improved by configuring the sanction component of the policy with a high (perceived) sanction severity. Whether or not side-effects occur and if they outweigh the benefits needs to be evaluated. Additionally the study by [31] can lead to the insight and design decision that a linguistic framing around morality can serve as a self-regulatory approach for users who consider deviation from their moral beliefs to be taboos. [32] show the effects of various password selection methods to password strength and password memorability. It can help improve a design by striking a balance between computational password strength and users ability to memorize, which – as we learned from [29] – decreases the need for subvert user coping mechanisms.

5 Discussion and Limitations

Many arguments in the ongoing philosophical exchanges about behavioral and design science are tied to the rigor-versus-relevance debate. A certain polarization of the debate has led to a wide-spread belief that behavioral science research is rigorous, but lacks (practical) relevance and merely triggers “so what?” reactions. Design science research on the other hand has been strongly characterized as being relevant, which is allegedly attained through a disregard for scientific rigor. We believe that these allegations are true to a certain degree.

However, the labels and strong polarization (and thus the cliff created between these two science paradigms in ISR) is hindering our ability to improve either – whether to make behavioral science more relevant or making design science more rigorous. In our research we took a new – to some extend naïve – look at the two paradigms based on the type of knowledge both generated from and required for research in the respective fields.

Our framework structures sources of different types of knowledge, their possible interaction with each other and allows in conjunction with e.g. the design science process model by [19] a structured enrichment of the design science research process with empirical knowledge. We believe such a design process to be more rigorous from a design science perspective. At the same time it allows behavioral scientists to showcase the relevance of their work by proxy of design artifacts.

Four points of where empirical knowledge can be injected into design science research have been identified. Using well-established work in this field we anchored these types of application with references in [2] and [19]. We imagine two possible types of use for our framework: 1) planning and structuring of design science research and 2) evaluation of design science research (with a focus on the rigor). The brief example gave a glimpse in how the framework can help with planning and structuring the design of an artifact. Our framework does not give guidance on what steps constitute design science research. Instead we show what types of empirical knowledge can be used in what phase of designing an artifact.

Another way of applying the framework is to evaluate design science research with it. In this scenario the four types of application of empirical knowledge can be used checklist-like. E.g., it can be used to determine if there is enough empirical evidence for the problem statement, which drives the motivation for the design of an artifact.

There are, however, limitations to the presented research, which we need to point out. We believe the philosophical discussion regarding episteme and techné to be sound. However, we did not introduce the three other Aristotlean virtues of thought phronesis, sophia, and nous. Therefore, we do not e.g. refer to ethical aspects or experience (in the sense of wisdom) although these cannot be deemed irrelevant, especially not in design science research practice.

Additionally, while we describe integration points with work by [2] and [19], we have not yet tested and evaluated the extent of possible integration between our framework and the design science process model or the design science guidelines. While we appreciate the ability to stand on the proverbial broad shoulders by "sourcing" both the process and normative component, it remains to be analyzed whether these two components need to be adapted for the specifics of rigorously empirical knowledge driven design science research.

Lastly, our presented example is brief in nature and a more comprehensive case study would be desirable to demonstrate the application of the framework for the structuring of design science research. Also an additional example showcasing the ability to evaluate design science research is required.

6 Concluding Remarks and Future Research

The goal of our paper was to examine how the interplay between behavioral (empirical) and design-oriented research (including artificial phenomena) can be improved from a design science perspective in ISR. Our research led to the distinction between empirical and theoretical knowledge (episteme) as well as non-artifact-centric and artifact-centric knowledge. To the best of our knowledge, a slightly related view can only be found in [20], what she calls theorizing about artifacts in use, and vaguely also in [6], what they call design knowledge.

Our framework allows the structuring of design science research and supports the design practice with empirical guidance. We claim that the application of theoretical and empirical knowledge in design science can improve the rigor of research. Our framework gives an idea of how behavioral IS knowledge, which frequently is criticized as lacking relevance [1, 33], can gain significant relevance by proxy; through its application in design science. This is done by aiding the problem definition and motivating the design of an IT artifact as well as supporting design decisions. There are still some open questions left which imply the need for further research. The explicit view of artifact-centric research as an own research stream is quite new. Therefore, it is unclear whether the outputs of this research are theories about artifacts or just a kind of weaker knowledge comparable to technological rules. Additionally, the question might arise who has to perform this research. Does it belong to the domain of design science or is it research in the behavioral science? We also recognize a need for more research on the four types of application of empirical knowledge, because no claims on the completeness of our list can be made as of now. Additionally, a deeper analysis of the characteristics of the different knowledge types might enhance our understanding of the interplay between the four quadrants.

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