Towards a Method for Design Principle Development in Information Systems

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Abstract. A central goal of doing research is to make findings available to the academic and practitioner community in order to extend the current knowledge base. The notion of how to generalize, abstract, and codify knowledge gained in design endeavors is a vital issue in design science, especially in the strand of design theory. Design principles provide a medium to make such design knowledge available to others and to make it transferable from a single application onto more scenarios that are subject to similar boundary conditions. The study proposes a preliminary method for the development of design principles based on a structured literature review and the inductive derivation of methodological components from it. The purpose of the method is to give researchers and practitioners executable steps to generate design principles.

Keywords: Design principles · Method · Design theory · Taxonomy

1 Introduction

Researchers and practitioners that *design* are concerned with the creation of meaningful artifacts that solve an organizational problem [1]. Quintessentially, the act of designing anything may be understood as the iterative transformation of an undesirable problem-state (*problem space*) to a more desirable solution state (*solution space*) through the use of artifacts [1–4]. Artifacts, generally, differ from natural objects, as they come into existence by design, i.e., with intended functionalities, with one or multiple authors, and, ultimately, to serve some human purpose [5–7]. In that, it is the process of analysis and understanding of how the constituent components of an artifact come into being that shapes the act of *designing* [8]. During that process, the designer generates *design knowledge*, which requires codification in a conceptual shell in order to be made useful for a broader user base and to contribute to the persistent knowledge base [9]. *Design knowledge* is knowledge about the artifacts, how they are constituted, and how they come into existence [10]. A central goal of *Design Science* is to accumulate design knowledge [11] and to make it available [12] so that it can be reused in multiple instances and to elevate knowledge gained about a singular solution to a more generally applicable level [13, 14]. The common purpose of design principles is to codify design knowledge and, given the consideration of respective boundaries, enable its reuse [15]. Additionally,

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design principles (as a part of design theory) should assist the designer in bringing about an artifact that has a set of specific functionalities and result in the expected effects [16]. Research on design principles and, more generally, design theories is beneficial as they enable the "(…) progression from an abstract level of situated implementation to a more generic and applicable level" [17 p. 4], and, subsequently, they "(…) would be a significant enhancement or addition to the existing scientific body of knowledge" [18 p. 5]. The medium of *design principles* is useful to codify *design knowledge* and to make it available as prescriptive guidelines that support design both as a *process* and a *product* [19]. [20 p. 227] defines *prescriptiveness* as "(…) if you want to achieve Y in situation Z, then perform action X."

As of now, there are a plethora of ways to develop design principles with studies varying vastly in their development approach. For example, some studies employ Action Design Research (ADR) and follow the notion of eliciting design principles reflectively from a design process or finished artifact [4, 13]. Other studies derive design principles in Qualitative Studies, Case Studies, or using Design Science Research (DSR) methods (e.g., [21]), with some employing the concept of *meta-requirements* (requirements addressing a class of artifacts [22]) and some skipping them. As of now, studies propose conceptual guidelines and frameworks to develop (nascent) design theory, of which design principles are an integral component (e.g., see [18, 23, 24]), yet, however, there is lack of an operationalizable set of steps to develop them. Thus, we see a need for a standard set of steps summarized in a method to assist design principle development according to both best practices established in the literature and epistemological foundations provided by the core literature on design theory. The present article proposes, firstly, a taxonomy of design principle development approaches generated from a structured literature review and, secondly, derives from it a method with specific steps representing the key tasks for their design. Because of the above, the research question of the present article is:

Research Question (RQ): Which steps need to be followed to develop design principles successfully?

The paper is structured as follows. Firstly, after the introduction, we illustrate the conceptual foundations of design principles. Section 3 describes the approach to identifying relevant literature and the research design in general. Subsequently, Sect. 4 starts with taxonomizing the inductively gained insights from the literature review and proceeds to derive a method from them. Lastly, in Sect. 5, we discuss our findings, explicate the contributions, and define the limitations of our work.

2 Design Principles

The term "design principles", as a linguistic composition, consists of two parts, namely *design* and *principle*. First, *design* (as a verb) can be defined as "(…) the process in which the designer progresses from a description of requirements to a model of an IS artifact (…)" [2 p. 2]. A principle, on the other hand, can be defined as "A fundamental rule or law, derived inductively from extensive experience and/or empirical evidence, which

provides design process guidance to increase the chance of reaching a successful solution." [25 p. 2]. Subsequently, we can establish the understanding of design principles, linguistically, as fundamental propositions that aid designers in achieving a successful transfer of requirements to design. That notion is widely supported by authors from the field, from which Table 1 shows selected definitions.

Table 1. Selected definitions of the term "design principle".

Definition
"As a definition, consider a design principle as a 'recommendation or suggestion for a course of action to help solve a design issue'" [26 p. 357]
"Design Principles (in so far they are considered a form of design knowledge) represent knowledge that is codified, explicit knowledge, readily accessible as prescriptive statements" [15 p. 39]
"The design principles capture the knowledge gained about the process of building solutions for a given domain, and encompass knowledge, about creating instances that belong to this class (…)" [13 p. 45]
"(…) are design decisions and design knowledge that are intended to be manifested or encapsulated in an artifact, method, process, or system" [27 p. 17]

Even though it is their purpose, design principles, per se, cannot directly be transferred onto any given application context, but rather are constrained by boundary conditions set both by the environment that they are supposed to be used in an by the experience of the user [11, 28].

The objective of design principles is supporting the design of artifacts, design principles as such are at a higher, "meta" level. However, design principles themselves often are the product of a DSR endeavor themselves [29, 30]. That makes them an artifact in the traditional, philosophical sense, i.e., an artificially designed (conceptual) object, which is different from natural objects that come into existence to fulfill some human purpose with specific functionalities [7]. To position design principles in the sphere of artifacts but at the same time demarcate them from *material* artifacts (usually, methods, models, constructs, and instantiations [5]) [30], one might employ, e.g., the *termini meta-artifact* [31], or *abstract artifact* [30].

Following the duality of the term design, as both a verb and a noun, design principles may both address the process of designing an artifact (i.e., the *development process* [32]), as well as its functionalities (i.e., the *system features* [32]) [22]. The literature provides various ways to further classify design principles in detail, e.g., through their inclusion as parts of design theories, as principles of form, principles of function, or principles of implementation [33].

3 Research Design

Our research approach is a structured literature review, as proposed by [34–36]. As it is our goal to construct a method for design principle development based on findings

in the literature, we set the scope of our search strategy to only include those papers that explicitly deal with the development of design principles, i.e., have, in our view, identifiable methodological components [37]. Next, the scope of our study delimits the methodological frame onto design science and the domain of Information Systems (IS).

To construct a nexus of literature that is as relevant as possible to the study, we search explicitly for the occurrence of the term "design principle" or "design principles" in the *titles* and *abstracts,* respectively, in the AISeL[1] database. The literature core is extended, on the one hand, through backward search [36] and reduced, on the other, through eliminating doubles and papers that are out of scope. The search was restricted to AISeL, as, during the search process, it became clear that the theoretical saturation has been achieved and that, most likely, no new information could be gained by incorporating additional databases and also extensive backward searches [36, 38]. Subsequently, the study does not claim completeness but instead builds upon a representative, methodical subset [37]. We started with 251 papers, of which, after both reduction and extension, 97 remained for more in-depth analysis.

We focused on papers presenting completed research studies on design principles (in terms of design theory), yet, if the method used to develop design principles was sufficiently recognizable, we also included Research-in-Progress papers.

4 A Method for Design Principle Development

4.1 Taxonomizing Features of Design Principle Development

Based on the literature review outlined in Sect. 3, we chose an inductive approach, in that we taxonomize different approaches to design principle development in the literature. Using a taxonomical approach is especially suitable, as it enables us to give structure to the field of design principle development and to identify central dimensions and characteristics [39], which we, later on, transfer into methodological components. We have identified seven dimensions and corresponding characteristics (see Table 2) that are suitable to map the development process according to our literature search [39].

Table 2. Taxonomy of development approaches. EX = Exclusivity, ME = Mutually Exclusive, NE = Not Mutually Exclusive. Unknown or Unspecified characteristics have been omitted.

Dimension (D_n)	Characteristics (C_{nm})					EX
Perspective	Supportive			Reflective		NE
Research Design	DSR	A(D)R		Qualitative	Case Study	NE
MR Source	Literature	Theory	Interviews	Workshops/ Focus groups	None	NE
DP Design	Derived	Extracted		Responsive		NE
Iterations	Single			Multiple		ME
Evaluation	Expert/User Feedback		Instantiation/ Field Testing		Argumentation	NE
Formulation	Free			Based on Template		ME

[1] https://aisel.aisnet.org/do/search/.

The *Perspective* **(D_1)** dichotomously classifies the design principles alongside two characteristics. First, *Supportive* **(C_{11})** design principles assist the design of an artifact *ex-ante*, i.e., before the design process has started and thus justify future design decisions [40, 41]. On the other hand, *Reflective* **(C_{12})** design principles emerge after or during the design iterations of the artifact. The dimension is not mutually exclusive as, naturally, the designer may produce design principles before the actual designing of an artifact, but may, at any point in the design process, refine them or add new ones.

Each design principle has some *Research Design* **(D_2)**, either as the central artifact (or *meta-artifact* [31]) to be developed or as part of a more extensive design process. Most prominently, design principles emerge alongside *Design Science Research (e.g.,* [21]), **(C_{21})**, *Action (Design) Research* [13] **(C_{22})**, *Qualitative Studies* **(C_{23})**, or *Case Studies* **(C_{24})**.

Next, studies differ in their approach to *Meta-Requirement elicitation* **(D_3)**. Meta-Requirements are derived from one or multiple sources, such as *Literature Reviews* **(C_{31})**, derived from *Kernel Theories* (i.e., Service-Dominant Logic) **(C_{32})**, *Interviews* **(C_{33})**, or *Workshops* **(C_{34})**. However, not all studies employ the concept of meta-requirements **(C_{35})**. For example, studies using *ADR* to derive reflective design principles usually do not derive meta-requirements before design principle development, as they are extracted rather than developed *a priori.*

Our findings show that design principles are *generated* **(D_4)** in three ways. Firstly, by *deriving* **(C_{41})** them directly (without meta-requirements) from a suitable knowledge base (e.g., Literature, Theory, or Case Studies), by *extracting* them from an on-going or finished design process **(C_{42})**, or by formulating them as a *response* to meta-requirements (even though, some authors use different terminology, e.g., *design requirements* [42]) **(C_{43})**.

Design principle generation can be iterative **(D_5)**, which is why we distinguish between *Single* **(C_{51})**, and *Multiple* **(C_{52})** iterations.

We see three evaluation strategies that are usually used in studies developing design principles **(D_6)**. Researchers may employ the assistance of experts (e.g., in interviews or workshops) **(C_{61})**, provide illustrative documentation *via* instantiation or field testing of the corresponding artifact **(C_{62})**, or, lastly, give argumentative reasons, e.g., by constructing a scenario, about the quality of the design principles **(C_{63})**.

Lastly, scholars, either formulate **(D_7)** *freely*, with the restriction being that the design principle is formulated prescriptively **(C_{71})** or based on a *linguistic template* **(C_{72})**.

4.2 Method-Elements

The following section explains the **Method Components (MC)** derived based on the taxonomy shown in Table 2 and the findings of the structured literature review. The focus lies on the strand considering supportive design principles, both because of spacing limitations, as well as the intuitive and self-explanatory nature of the reflective approach. Furthermore, our literature review shows that the supportive approach is characterized by methodological heterogeneity rather than the reflective approach, which predominantly utilizes ADR or methods of DSR. Figure 1 visualizes both approaches as a procedural model. Additionally, the method represents and overarching framework, which, hopefully, spurs creativity in designers by conducting the individual steps necessary for design

principle development, yet, leaves the instantiation of each activity flexible. Thus, we provide typical best practices that we have derived from the literature review (e.g., visualizing the relationship between design principles and meta-requirements or using a template for their formulation).

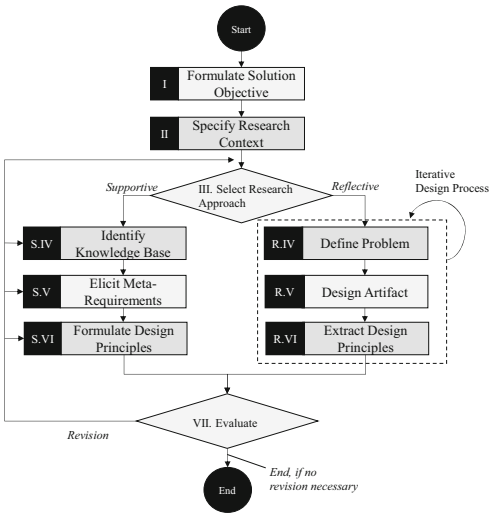

Fig. 1. Method for Design Principle Development.

ME I - Formulate the Solution Objective (SO): The first step in developing design principles is to formulate their purpose. Their purpose, generally, is to support the design of an artifact successfully. That objective can be called *Solution Objective*, i.e., the formulation of the specific task the artifact should, at some point, be able to fulfill [23] (see Table 3). The goal of **ME 1** is to present the purpose of the design principles concisely and precisely.

Table 3. Exemplary Solution Objectives formulated in design principle development.

Exemplary Solution Objectives
"What are appropriate design principles for tools that allow for reflecting sustainability in business models?" [43 p. 2]
"Which data-specific design principles can be used to assess business model representations regarding their applicability for data-driven business models?" [44 p. 2]

ME II - Specify Research Context: Once the general direction of the research endeavor is set, the researcher must select an adequate research method. Design principles may both be the part of a more comprehensive research endeavor and come into

existence during that process, or they might be the artifact themselves. For example, if the study includes close interaction with practitioners and collaborative design of an artifact, the choice could fall on ADR (e.g., see [45]). However, if the design principles were to be designed *ex-ante*, e.g., from interviews, one might opt to conduct a qualitative study to develop them (e.g., see [46]). Table 4 gives three examples of design principles and their corresponding methodological research context. Design principle development may span multiple studies and experience refinements in subsequent research projects.

Table 4. Examples of different research contexts for design principle development.

Design principles	Research context
DP to asses business model representations for data-driven business models [44]	Qualitative Study
Multiple DP for Blended Learning Services [48]	ADR [13]
DP for attention aware BI & Analytics dashboards [49]	DSR [50]

ME III - Select Research Approach: We propose a dichotomous decision between, firstly, a *Supportive* approach and, secondly, a *Reflective* approach. The primary difference between both approaches is the point of artifact design and the logic of generating design principles. In the *supportive* approach, the goal of design principles is the provision of design knowledge in advance to support the design of an artifact before the design process takes place. These design principles are derived in advance from the literature, kernel theories, case studies, expert interviews, or comparable, suitable sources for design knowledge. Contrarily, the *Reflective* approach means that a design action has been taken, and "(…) reflecting on what has been done is required (…) and design principles need to be abstracted" [47 p. 7]. Design principles can be reflected in one's own design processes or those carried out by others [4, 10, 33]. Thus, we follow the terminology of [4] and name that approach *Reflective*. Generally, this distinction is in alignment with the inductive and deductive understanding in the epistemological loop of *relevance* and *rigor* in DSR outlined in [18].

ME SIV/S.V - Identity Knowledge Base/Elicit Meta-requirements:
Meta-Requirements, as proposed by [22], refer to requirements addressing a class of artifacts. In that, these requirements need to be abstract and general to be valid for more-than-one instances [51] (see Table 5). While the origin of meta-requirements lies in the construction of a *design theory* and their derivation relied on using kernel theories, today, multiple studies show various possible backgrounds. These include, exclusively or in combination, the derivation from theory, literature, interviews, or similar suitable data sources. Suitable data are all data that assist the researcher in extracting design knowledge (e.g., [52] argue for using user-review from an online software comparison portal to derive design principles). No matter their origin, meta-requirements need to be tied directly to the solution objective to ensure the continuity of the red path throughout design principle development [23].

Table 5. Examples of *meta-requirements* and *design principles* from the literature corpus.

Exemplified Meta-requirement	Source
"Full accessibility to project insight database for all organization members" [53 p. 12]	Interviews
"**MR1:** Record user's eye-movement data with an eye-tracking device while processing visualized information." [49 p. 5]	Literature
Exemplified Design Principle	Template
"Provide the collaboration system with **communication medium** that have at least **one high** and one **low level** of **synchronicity** (…) to build consensus for efficient collaboration among them." [54 p. 7–8]	[28]
"Frame the ill-structured problem by developing an ontology in which the main components of the problem and their relationships are modeled." [55 p. 403]	None

Our literature review has shown that only a few studies employ the concept meta-requirements while extracting design principles from a designed artifact, e.g., in the context of an ADR-Study (an example would be [53]). Usually, meta-requirements are derived from the literature in developing supportive design principles *a priori* to any instantiation of an artifact.

Even though not all studies employ meta-requirements, we include this step in the method (for supportive design principles), as we agree with the concept of *Value Grounding* explained by [24], which proposes a close link between design theory and the corresponding goal that it intends to achieve (i.e., the *causa finalis* [33]). Correspondingly, supportive design principles mandatorily should address at least one or multiple *meta-requirements* (which may be aggregated to *key requirements*) [18, 23].

ME S.VI - Formulate Design Principles: Design principles are formulated twofold. Firstly, they must include specific, prescriptive instruction for an artifact design (content), that addresses meta-requirements [23]. A precise tool to visually illustrate that correlation is the mapping diagram (see Fig. 2) that shows which design principles address which requirement. Thus, we recommend visualizing the connection and derivation logic between design principles and meta-requirements as a mapping diagram mandatorily to giver ready, easy, a visual aid to understand the connections. One step further, some authors extend another layer and append, e.g., design features that result from design principles. Second, when formulating design principles, the researcher can draw from established templates. In [19], the authors identify six formulation templates, namely

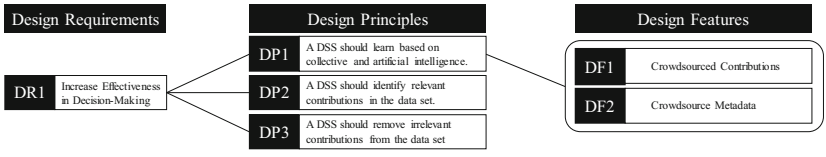

Fig. 2. Example of mapping diagrams. The excerpt is taken from [42 p. 2662].

[20, 22–24, 28, 56], and provide enhanced guidelines themselves. For examples of design principle formulation, see Table 5.

ME VII - Evaluate: The literature on *design theories* and *design principles* offers multiple underlying conditions that design principles need to fulfill. Our literature review has shown ways to evaluate design principles (see Table 2), such as *Expert Feedback* (Interviews, Workshops), *Instantiation,* or *Argumentation.* To support a goal-oriented evaluation of design principles, we provide two categories of evaluation criteria.

First, design principles should be correct in form. Meaning that there are some necessary conditions, let us call them the smallest common denominator, that design principles need to fulfill in order to be called so. Thus, design principles need to prescribe, precisely, a specific action, a prescription to bringing an artifact into existence through the codification of design knowledge (**Prescriptiveness**) [9, 13, 26, 27, 57]. Next, the design principle should be adequately general in order to address a class of artifacts, rather than one specific instance (**Abstractedness**) [13, 28, 32, 33, 58].

Arguably the most crucial purpose of design principles is to make design knowledge reusable in different application scenarios as if that is not so, their very meaning and purpose, i.e., their "(…) practical ethos (…)" is lost [59 p. 1]. Thus, we draw from [59], who propose a framework for light reusability evaluation of design principles, which can be used as tools for argumentative justification or evaluation. The framework consists of five criteria, namely *Accessibility*, *Importance*, *Novelty & Insightfulness*, *Actability & Guidance*, and *Effectiveness.*

5 Contributions, Limitations, and Outlook

The present study develops a method for design principle development based on the taxonomized results of a structured literature review. Thus, our **scientific contributions** lie in assisting researchers in developing design principles in a research setting that is not as clear cut as, e.g., design principle elicitation in ADR. We outline a way to generate design principles in alignment with epistemological underpinnings based on different types of knowledge bases. Additionally, we collect, contextualize, and synthesize approaches to design principle evaluation and propose essential properties that design principles need to have. Thus, our work assists in extending the scientific body of knowledge by providing a method that makes design principle development more structured, applicable, and goal-oriented. Through generating more design principles, the paper, indirectly, contributes to extending the body of design knowledge [18 p. 5]. Lastly, while there have been some studies providing guidelines in generating design principles (e.g., [13, 18, 41]), we argue, that ours contributes merit through its operationalizable nature and, through the conjoint utilization of the taxonomy, gives advice on possible, underlying knowledge bases and best practices.

As far as **managerial contributions** are concerned, we argue that through the support of design principle development, we enable researchers and practitioners to make their attained design knowledge available and, subsequently, assist their users in implementing them in their new design endeavors. Ultimately, through providing well-founded design

principles, our method helps the generation of excellent designs, which "(…) can go far beyond a single success story." [11 p. 186].

Lastly, our work is subject to **limitations**. As the data on design principle development stems from AISeL, we restrict our view only on Information Systems, which leaves the potential for further research in additional databases. Also, using only the keywords "design principle" and "design principles" excludes, at this point, synonyms, which need to be investigated further. Thus, it is likely that not all papers developing design principles were found and that broader inclusion of databases and publications covering design science, in future work, is necessary. Also, the method only builds on publications purely developing design principles. Naturally, as they are part of design theory, the next step could be to extend the literature review and include methods for developing comprehensive design theories. For example, [60] give a detailed overview of publications thematizing design science. The method is yet a preliminary version and thus requires continuous testing and improvement, but is, as of now, an initial approach to operationalize design principle development and establish a best practice (in conjunction with the taxonomy given in Table 2. Future evaluation strategies could include conducting focus groups, checking the method for applicability (e.g., by using the framework of [61]), or instantiating it in a real-world design project. Currently, we plan to evaluate further and develop the method in both the academic research setting of universities, but also in applied research institutes. Additionally, the method could profit from a more structured underlying design framework, such as Method-Engineering, to enhance formalization and to zoom in on the activities even further.

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