Prescriptive Knowledge in IS Research: Conceptualizing Design Principles in Terms of Materiality, Action, and Boundary Conditions

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Abstract

In the IS discipline, the formulation of design principles is an important vehicle to convey design knowledge that contributes beyond instantiations applicable in a limited context of use. However, their formulation still varies in terms of orientation, clarity, and precision. In this paper, we focus on the design of artifacts that are oriented towards human use, and we identify and analyze three orientations in the formulation of such design principles in IS journals—action oriented, materiality oriented, and both action and materiality oriented. We propose an effective and actionable formulation of design principles that is both clear and precise.

1. Introduction

Prescriptive research occupies an indispensable position in the repertoire of the information systems (IS) discipline [1, 2], next to explanatory and predictive research. Prescriptions or guidelines are essential in order for theory to be applicable in practice, and to fulfill the all-important goal of improving organizational practice and, ultimately, social well-being [2]. The goal of providing prescriptive or design knowledge has been discussed by various authors [3-5] and the field of design science research (DSR) has gained prominence, as evidenced by publications and special issues in our discipline's major journals (e.g., *MIS Quarterly)* and by dedicated conferences (e.g., *International Conference on Design Science Research in Information Systems and Technology)*. However, design-oriented work is still relatively scarce, for instance, ”less than 5 percent of all new submissions to MISQ reflect design science work“ [3, p. iv]. DSR focuses on the development of purposeful artifacts that are useful to individuals, organizations, or society at large. The prescriptive knowledge provided by DSR provides a basis for translating theory into practice, and vice versa [4, 6].

Design knowledge can take different forms at different levels of abstraction, including constructs, technological rules, models, methods, design principles, or full-blown design theories [4, 7]. One important vehicle to convey design knowledge that contributes beyond instantiations applicable in a limited use context is that of a *design principle* [4, 7]. Despite their obvious relevance, however, there is a lack of convention as to how design principles should be formulated and what exactly a design principle is. It seems to be taken for granted that a design principle is simply a design principle if introduced as such. Although frameworks about the formulation of design knowledge or design theory have been proposed [e.g., 7, 8], the formulation of design principles has not been given its deserved attention.

Recently, some authors have begun to present their design principles in designated sections in their reports [e.g., 9, 10]. The interested audience can thus read the section and know what is prescribed, instead of drawing a conclusion from reading a complete report. Moreover, one does not have to infer the prescription, because it has been explicated. However, the various formulations of design principles differ widely and this problem leads us to our first research question (RQ):

> ***RQ1:*** *What are the primary orientations in the formulation of design principles in the IS discipline?*

If we take medical prescriptions as an analogy, we can see that a prescription should be neither too broad nor too lengthy in order to be actionable. For instance, there are few cases—if at all—where a medical prescription is comprehensively described in ten pages, complete with sufficient knowledge of the underlying biological mechanisms in terms of cause-effect relationships. It is probably because this level of detail is unnecessary for a well-trained pharmacist and reading ten pages would cause a delay in dispensing the required medicine. The doctor can communicate with the pharmacist at a level of detail (abstraction) that is appropriate for both of them, given their assumed background knowledge.

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In analogy to medical prescriptions, indeed, we can argue that design principles should be neither too broad nor too lengthy—but is that all? We can perhaps find other clues by looking at what has been done so far. If different orientations in the formulation of design principles are identified, we might be able to argue which of them is effective. Correspondingly, our second research question is:

> ***RQ2:*** *What are the characteristics of effective design principle formulation?*

The objective of this paper is therefore to explore the different ways in which design principles have been formulated in leading IS journals. Through this exploration, we seek to arrive at a framework to analyze design principles and perhaps any other guideline or prescriptive knowledge that concerns IS. We then propose an effective formulation of design principles, grounded in our analysis.

2. Theoretical Background

2.1. What Design Principles Are

According to Sein, Henfridsson, Purao, Rossi, and Lindgren [11, p. 39], a design principle captures "knowledge about instances of a class of artifacts." In addition, Hevner and Chatterjee [12] mention that "a principle can also be formed as a rule or a standard of conduct" [p. 66]. In their book *Universal Principles of Design,* Lidwell, Holden, and Butler [13, p. 12] explain that "the concepts in this book, broadly referred to as 'principles' consist of laws, guidelines, human biases, and general design considerations." This reference is somewhat broader than the previous definition.

A better understanding of design principles inevitably requires an elaboration on what these principles are all about. Gregor and Jones [7] identify three general phenomena of interest to DSR—material artifacts, human understanding of artifacts, and abstract artifacts—grounded on Popper's three worlds, the physical, the subjective realist, and objective knowledge [14]. While material artifacts exist physically (e.g., product or process), abstract artifacts are rather intangible and take the form of such things as models, methods, constructs, or theories. The last phenomenon relates to how people conceptualize their understanding of artifacts. Design principles can then be formulated based on understanding and experience with material artifacts, or derived from abstract artifacts [7, 15].

In Gregor's taxonomy of theory types in IS Research [16], design principles fall into the class of theory for design and action. This type of theory "gives explicit prescriptions (e.g., methods, techniques, principles of form and function) for constructing an artifact" [p. 620]. A design theory comprises a number of component parts, including that of principles of form and function that define "the structure, organization, and functioning of the design product or design method" [7, p. 325].

A similar concept was introduced earlier as technological rules by Bunge [17], describing a sequence of how one should act to attain predefined goals. Niiniluoto [18] proposed considering the technical norms in DSR, which connect prescription to kernel theory. From these different definitions and explanations, we can conclude that a design principle is a statement that prescribes what and how to build an artifact in order to achieve a predefined design goal.

2.2. Why Design Principles Matter

Design principles are important on at least three accounts. First, design principles can be used to capture and communicate essential design knowledge. Second, the formulation of design principles allows abstracting away from singular settings and thus generalizing prescriptive knowledge. Third, it has been articulated that "the construction of an artifact and its description in terms of design principles, and technological rules are steps in the process of developing more comprehensive bodies of knowledge or design theories" [4, p. 341]. We can thus infer that, without the explication of design principles, the difference between DSR and practical design is almost unnoticeable. The opinion is shared by Iivari [1, p. 56] who put forward the thesis that "design product and design process knowledge, as prescriptive knowledge, forms a knowledge area of its own and cannot be reduced to the descriptive knowledge of theories and empirical regularities." Design principles interpret descriptive, explanatory, and predictive knowledge—which can be referred to as the kernel theory—into something that can be used in the practice of building purposeful IS artifacts.

3. Methodology

A literature review was conducted where the unit of analysis was the individual journal article that presents a set of design principles. We took into account principles for both design processes and products, following Gregor and Jones' [7] argument that design theories are about products and methods or processes, and consistent with the view that artifacts can be constructs, models, methods, and instantiations [4].

In a first step, we searched for literature in a database consisting of eight top IS journals according to the AIS Senior Scholar's Basket of Journals using "design principle" as the keyword (see Table 1). Topics of interest and research approaches vary across these publications, with some focusing on the managerial and social aspects of IS and others on the technological aspects of IS. We do not claim that our analysis of published papers is exhaustive as we limited our search to the AIS basket. Still, we expect these studies to constitute an appropriate sample to analyze how design principles are currently formulated in the scholarly IS discipline. Table 1 provides an overview of the journal coverage and the number of articles.

Table 1: Journal coverage

IS journals	Coverage	*n*
European Journal of Information Systems (EJIS)	1991-2013	786
Information Systems Journal (ISJ)	1996-2013	321
Information Systems Research (ISR)	1990-2013	448
Journal of Association of Information Systems (JAIS)	2000-2013	251
Journal of Information Technology (JIT)	1986-2013	826
Journal of Management Information Systems (JMIS)	1984-2013	942
Journal of Strategic Information Systems (JSIS)	1995-2013	561
Management Information Systems Quarterly (MISQ)	1977-2013	911
Total		5046

The database was screened in a second step, where we used three keywords to search for formulated design principles: "design principle," "principle," and "guide." This process yielded 183 articles, many of which were then filtered out, because the term "design principle" was found only in their reference lists, or it was only mentioned once without neither implication nor further elaboration. This process left us with 83 articles. Afterwards, almost half of the articles were excluded from the list, because they did not contain any design principle, either formulated or cited. We finally divided the remaining 43 articles into those that formulated design principles (*n*=30) and those that cited design principles (*n*=13). Any cited design principle that had also been mentioned as a formulated one was omitted from further analysis to avoid double entry. Table 2 provides an overview of the number of articles reviewed during this screening step.

Table 2: Literature search

IS journals	1st screening	2nd screening
EJIS (1991- 2013)	9	5
ISJ (1996- 2013)	9	7
ISR (1990-2013)	11	4
JAIS (2000- 2013)	17	7
JIT (1986-2013)	8	2
JMIS (1984-2013)	10	8
JSIS (1995-2013)	1	-
MISQ (1977-2013)	18	10
Total	83	43

In reviewing the remaining 43 articles in the third step, we aimed at finding similarities and patterns among them, which could be used to categorize the articles, for instance, in terms of the content of design principles or the style adopted to formulate them. We created a list containing all identified sets of design principles in the 43 articles. The list was analyzed in a session, where the first and second author discussed whether similarities could be identified across the sets of design principles and to what extent these similarities could be grouped together. Our analysis revealed that some of the design principles encapsulated users' utilization of artifacts (i.e., focused on action), others talked mainly about the artifacts and very little about the users (i.e., focused on materiality), and the remainder described both (i.e., focused on both materiality and action).

In the fourth step, the first two authors coded each set of design principles independently using the identified orientations before comparing their results to attain an inter-rater agreement. We decided to code sets of design principles instead of individual design principles. We do not, however, disregard the possibility that a set consists only of a single design principle. Both raters agreed in the majority of the coding results, which were done individually. The agreement demonstrates that, out of 43 sets of design principles, 6 of them were formulated action oriented (i.e., focusing on what can be done with the artifact), 12 used materiality oriented formulation (i.e., focusing on how the artifact should be designed), and 16 were both action and materiality oriented design principles (i.e., focusing on both what can be done with the artifact and how it should be designed). This leaves us with 9 sets of design principles, upon which the raters disagreed. We address the problems that have led to these disagreements and propose an effective formulation of design principles to increase consistency, precision, and generalizability in the discussion section. We believe this step is necessary in determining the possible cause of disagreement in the interpretation of design principles. The possible solution is then proposed in order to avoid similar issues in the future formulation of design principles.

4. Findings: The Primary Orientations in Formulating Design Principles

The three identified orientations in formulating design principles (Table 3) correspond to the primary orientations in IS research that traditionally (a) focus on the technology, (b) the use of technology, or (c) both [19]. From our analysis, it becomes noticeable that, for instance, those principles that consider both action and materiality pertain to the research paradigms which study the interaction between the social and the technological [see [20-23].

Our analysis suggests—at least in the sample that we studied—a clear focus on design principles for socio-technical systems, that is, principles for the design of artifacts that are intended for *human use.* Still, IT can also be oriented towards *non-human use*. Based on our analysis, we thus focus on what may be referred to as design principles for socio-technical systems. In what follows, we will provide an overview of the three identified categories. Some notes clarifying the way in which we interpret the terminology are provided in the Appendix.

Category 1: Action oriented design principles give prescriptions about *what* actions the artifact allows for. Design principles that fall under this category generally say "the system should enable this or that" or "the system should allow users to do this or that," thereby exhibiting a clear focus on human use.

An example for this orientation is a set of design principles formulated for communication on the internet [24, p. 341]. The principles prescribe, for instance, "to provide an open forum to all interested persons and groups who have access to the internet" and "to facilitate the discourse." It can be concluded that that the authors of this paper formulated their design principles from the point of view of human users, thereby using metaphors of human activity, such as discourse and forum.

Table 3: Primary orientations in formulating design principles

Action oriented design principles
Describes only what actions a technical object should allow for. **Examples:** "Enable users to notice and bracket the presented data", "Build a house one can live in."
Materiality oriented design principles
Describes only the material properties of a technical object, that is, how the object should be designed or what components it has. **Examples:** "Provide a functionality to classify and rate data", "Build a house to have walls, a roof (principles of form), and doors that can be opened (principle of function) "
Action and materiality oriented design principles
Describes both the material properties of a technical object (how the object should be designed) and what actions it should allow for (what the object can be used for). **Examples:** "Provide functionality to classify and rate data to allow for noticing and bracketing", "Build a house to have walls and a roof and doors one can walk through, so that one can live there"

We soon realized that this kind of design principle does not provide any guidance about how to design, that is, the materiality of the artifact. A seemingly appropriate analogy for this weakness can be illustrated as a fitness trainer who says, "let your biceps contract" and then leaves everybody with barbells and other training equipment scattered around the room. The concern of those this advice is given to is about choosing the equipment to contract their biceps, but perhaps they end up choosing the wrong one or none. From this analogy, we understand that this orientation lacks effectiveness in formulating design principles. Table 4 provides an example of a set of primarily[1] action oriented design principles from the sample we analyzed.

Category 2: Materiality oriented design principles prescribe *how* an artifact should be built or *what* it should comprise. These design principles usually state "the system should look like this or that" or "the system should have this or that feature."

Ahrens and Sankar [25, p. 426], for example, suggest that designers should "use templates and provide concrete examples with solutions" and "adjust size of procedural step to size of cognitive process" to design a concept tutorial (see Table 5 for all design principles). This prescription focuses on material properties and does not say anything about action.

Table 4: Example of action oriented design principles [24]

Design principles
1. To provide an open forum to all interested persons and groups who have access to the internet 2. To facilitate the discourse. This duty is assumed by the editor(s) who can be any combination of the authors 3. To discourage the editor(s) from developing the position into a power base or structure, the role of the facilitator should not be monopolized nor permanent 4. To produce a neutral and transparent document to report all the undistorted views of all the participants of the discussion 5. To provide some mechanism of ensuring and for the participants to take on responsibility 6. To seek understanding and where possible true consensus rather than contrived conclusions.

While the intended use might be described elsewhere in the document (and this is indeed the case in the example), it is not part of the design principle itself. The weakness can be shown using the same fitness center analogy. This time, the trainer points to an exercise ball using one hand and two 1.5 kg barbells using the other hand while saying "exercise with these"—nothing further. Everybody else in the room, who happen to be in a group of beginners, can be expected to either do the wrong exercise, or to do nothing at all. Some would

[1] Through our coding, we identified *primary* orientations; in some cases, the primary orientations were not clearly visible, as evidenced by disagreements between the two coders, an issue that we address in the discussion section.

probably do the right exercise, but we should not leave things up to chance alone. Learning from this analogy, it is our contention that this orientation lacks effectiveness too. Table 5 provides an example.

Table 5: Example of materiality oriented design principles [25]

Design principles
1. Organize material in task-oriented structure
2. Use templates and provide concrete examples with solutions
3. Adjust size of procedural step to size of cognitive process
4. Provide instruction in problem solving context
5. Represent cognitive processes as a set of decision rules

Category 3: Action and materiality oriented design principles basically combine the two previously explained orientations, without favoring one over the other. They prescribe *what* an artifact should enable users to do and *how* it should be built in order to do so. In a more straightforward term, they prescribe "the system should allow users to do this or that by providing this or that feature." An example for this orientation is the set of design principles formulated for mobile and temporarily interconnected systems [26, p. 126]. These authors stated the following:

> The context switching support principle specifies that the system should support switching between physical and social contexts, i.e., support seamless transitions across contexts necessary for sustained services.

This design principle takes into account how the technical object should be built ("should support switching between physical and social contexts") together with what users should be able to do with it ("seamless transitions across contexts necessary for sustained services"). We can again use the fitness center analogy to illustrate this orientation: After noticing the confusion that is apparent on everybody else's face, the fitness trainer thought of addressing them differently. The trainer steps forward and walks to the exercise ball, collecting two barbells on the way. Reaching the spot, the trainer begins to speak, "Sit on the ball; let your biceps contract by lifting one barbell using each hand." Something else may be said, something else done, but it is not so much of our interest in this paper. After all, putting ourselves in their shoes again, we can see that everybody else understands what the trainer means and acts upon it. Learning from the fitness trainer analogy, we can see that considering both materiality and action is effective in formulating design principles—its clarity helps in understanding what action is possible using the materiality of an object. Table 6 provides an example of a set of design principles that relate to both materiality and action. Please note that not all of the individual principles describe both materiality and action, but the entire set does—we will discuss this issue later in the discussion section.

Table 6: Example of action and materiality oriented design principles [26]

Design principles
1. The service synchronization principle specifies that the NDI system should make selective services associated with the mobile device and deemed plausible for the car setting available to users.
2. The principle of contextually adapted manipulation posits that the user should be provided with device or service controls that are adapted to the spatiotemporal conditions of cars.
3. The context switching support principle specifies that the system should support switching between physical and social contexts, i.e., support seamless transitions across contexts necessary for sustained services.

5. Discussion

To begin with the discussion, we deem it necessary to emphasize that the principles we use as examples here are not to be considered as those which are bad or not useful. Our main intention is to search for a consistent way of formulating design principles in order to contribute to the development of developing and publishing prescriptive knowledge in IS.

5.1. The Problem of Inconsistency

Some of the reviewed sets of design principles show inconsistency in their orientation as some of the design principles in these sets were formulated as action-oriented and some as materiality-oriented. Consider two design principles below, which were formulated in a set together with four more principles [10, p. 445]:

> 2. The principle of user control: knowledge workers whose competencies were captured and stored in CMS would have control over their information.
> 4. The principle of real-time capture: CMS should track competence-in-use in real time. This principle addresses the problem of inaccurate competence data, which is caused by a CMS design focusing on past competence. The principle promises to generate data about competence as it emerges through knowledge work in action.

While principle number 2 was formulated action oriented (users should be enabled to have control over the information), principle number 4 was formulated materiality oriented (it describes the functions of the artifact). This inconsistency makes the design principles become difficult to apply in artifact building, as the orientation keeps shifting from action to the materiality without complete prescription of either. Such inconsistency also reduces the clarity as to whether the prescription refers to cause or effect, in other words, whether it means *how* an artifact should be built, or *for what* the artifact should be built. It is due to such inconsistencies that the raters disagreed on their coding as described earlier in this paper.

An analogy can help to illustrate this problem of inconsistency. Imagine the fitness trainer, to whom we have been acquainted before, gives a list of homework for the beginners. The list reads as follow: (1) Do four sets of push up, each set consisting of eight repetitions, (2) Do four sets of sit up, each set consisting of eight repetitions, (3) Let your triceps contract, (4) Use the exercise ball, (5) Use the barbells, (6) Let your biceps contract. While the list sounds correct at first, it is however inconsistent. One soon discovers that it is almost impossible to follow the last four items and starts to wonder whether the four of them are meant to be performed in combination with each other or rather independently. The latter is even more difficult as there are many different ways each of them can be performed. In addition, since these six items are written together to form a list, it gives an impression that each is part of a sequence. Failure to determine the correct interpretation may result in injury or poor achievement. Still, this list reflects how some of the reviewed design principles were formulated.

We believe this issue is related to the criticism addressed to the formulation and interpretation of design principles, which said that [27, p. 299]:

> Reliance on design principles could be dangerous too. Most web page design principles are based on qualitative, personal experiences, and as Shneiderman laments, they are often incomplete, lack generalizability, and some are even misleading.

5.2. The Problem of Imprecision

Another problem is that of imprecise formulations of design principles, which might be seen as incomplete or even misleading. We have found several cases where certain words are chosen without any further explanation about whom or which they refer to. Consider these statements: "a DSS will be technically easy to use and conceptually challenging" [28] or "make each IT capability simple" [29]. The coding results of both raters disagree on these two statements, as well as on seven other sets of design principles. While one coder interpreted "easy to use" to be an inherent characteristic of the DSS, the other believes it refers to how the users are expected to perceive the DSS. The same applies to "simple," which is interpreted as both "an uncomplicated structure of the IT capability" and "minimal effort requirement for the user to appropriate the IT capability."

It is thus clear that action orientation is perceived to be implied by the statements. One can say (and this is a declarative statement) "the barbell is heavy" to refer to the weight of the barbell and still be interpreted as implying "the barbell is difficult to lift because it is heavy." Then again, the misinterpretation would not have occurred had the statement been formulated precisely, such as "the barbell weighs ten kilograms." If the action orientation is really intended, then the following formulation is precise: "many people cannot lift the barbell without considerable effort," and even more precise by adding the information about its weight. We will elaborate this further in the next section.

5.3. Towards an Effective Formulation of Design Principles: Materiality, Action, and Boundary Conditions

In this section, we propose a conceptualization of design principles considering both materiality and action. Building on the previously proposed information systems design theory (ISDT) [7] and design relevant explanatory/ predictive theory (DREPT) [8], we suggest that a design principle should indeed contain both types of prescriptive knowledge.

Specifically, we suggest that an effectively formulated design principle contains three kinds of information: First, information about the actions made possible through the use of an artifact. Second, information about the material properties making that action possible. Third, the boundary conditions under which the design will work. In other words, a design principle should provide prescriptive knowledge about action *and* an artifact's material properties in terms of both form and function[2] under specified boundary conditions.

In their framework, Kuechler and Vaishnavi [8] placed DREPT between kernel theory and ISDT, which implies a sequence. While we agree with this idea of sequence, we believe that it would be more efficient and effective not to present DREPT and ISDT separately. Instead, the formulation we propose brings them together without emphasizing any of them. After all, it has been stated that "IS design theory shows the principles inherent in the design of an IS artifact that accomplishes some end, based on knowledge of both IT and human behavior" [7, p. 322]. A design principle, we argue, should reflect knowledge of both IT and human behavior, if the target user is human.

[2] Please see the Appendix for the relationship between principles of form and function on the one hand and action on the other.

In DSR in the IS discipline, we routinely think of a complex artifact. It was advised that, “when the design is complex in terms of the size of the artifact and the number of components (social and technical), then explicit extraction of design principles may be needed” [4, p. 351]. Consequently, an effective formulation of design principles can be achieved through a structure that is both clear and precise. The clarity can be obtained by demonstrating what material properties should be built using technology metaphors, in order to enable what action possibilities using metaphors of (human) action. The precision can be achieved by outlining boundary conditions, within which the design principle applies. The boundary conditions can be explained through a statement of relevant use context or intended user group. However, it is important that a design principle is formulated sufficiently abstract to leave some space for different instantiations in different contexts that share the defined boundary conditions. This, in turn, reduces the limit of generalizability previously lamented [27].

Our proposed formulation for design principles is consistent with the concept of affordance that is now predominantly used in the IS field to describe the actions that technology provides to human users [30]. While the term “affordance” was initially introduced by J.J. Gibson as “what it [environment] offers the animal, what it provides or furnishes, either for good or ill” [31, p. 127], it has been appropriated by IS scholars and is defined “as potentially necessary (but not necessary and sufficient) conditions for ‘appropriation moves’ (IT Uses) and the consequences of IT use” [30, p. 625]. An affordance is thus viewed as a relational concept [23, 32] even since its first introduction. According to Chemero, an affordance should have the following structure: “affords-φ (feature, ability)” [32]. If this structure is, for instance, applied to illustrate a climbing affordance, it says “affords-climbing (my leg length, riser height)” [p. 188]. Similarly, Gibson in his seminal work wrote “air affords breathing” [31, p. 130], “a large object needs a handle to afford ‘grasping’” [p. 133], and more specifically “an elongated elastic object, such as fiber, thread, thong, or rope, affords knotting, binding, lashing, knitting, and weaving” [p. 133].

Let us use the last example, assume it is valid, and formulate a design principle from it.

> **Proposition:** Objects having elongated form and elastic attribute, such as fiber, thread, thong, or rope, afford knotting, binding, lashing, knitting, and weaving.
> **Design principle:** Build an object to have an elongated form and elastic attribute, so that people can knot, bind, lash, knit, and weave it.

Importantly, we do not claim that the implementation of any design principle that is aimed at designing an object for human use leads to a certain effect in a deterministic manner. Instead, it is argued that it provides a potential for action [30].

We soon notice that this design principle only works given that the specified user group has acquired complete fine motoric skills and has an experience with knotting, binding, lashing, knitting, and weaving, may it be first hand or simply vicarious. These given characteristics belong to boundary conditions. Hence, design principles can be formulated in the following structure:

> Provide the system with **[material property—in terms of form and function]** in order for users to **[activity of user/group of users—in terms of action]**, given that **[boundary conditions—user group’s characteristics or implementation settings].**

As Herbert Simon once wrote that “artificial things are often discussed, particularly when they are being designed, in terms of imperatives as well as descriptives” [33, p. 15], we also delve into a similar discussion here. Imperative sentences typically express prescription, while declarative sentences express propositions [34]. It then follows that design principles, being prescriptive knowledge, are bound to be expressed through imperative sentences. However, while propositions can be tested and be assigned a true of false value, prescriptions cannot [35]. Nevertheless, a design principle can be converted into a testable propositional statement (e.g. if an IS intervention is undertaken, users will be allowed certain actions)

Moreover, it was once mentioned that “as the word ‘design’ is both a noun and a verb, a theory can be about both the principles underlying the form of the design and also about the act of implementing the design in the real world (an intervention)” [7, p. 322]. The abovementioned structure fulfils this requirement. It does so by mentioning the effect (activity of user group), the cause (material property of artifact), and the contexts where this cause can be expected to yield the effect (boundary condition). The level of abstraction and amount of detail needed in a design principle depend on the context. Furthermore, design principles translate kernel theory (i.e., typically explaining and predictive theory) into actionable, prescriptive statements.

This discussion leads us to the question about how to evaluate design principles. To answer this question, we must turn to the explicit goals of formulating design principles—indeed, the actual user of the design principle is the designer of the artifact. A designer follows the proposed design principle to build an artifact. Therefore, one way to measure the effectiveness of a design principle is to measure in how far it is actionable by the designer. In other words, we can measure whether—and how easy—the design principle can be instantiated into a concrete artifact, and whether this artifact indeed proffers the action described by the design principle. This is akin to the concept of instantiation validity proposed by Lukyanenko, Evermann, and Parsons [36, p. 322], which is "the validity of IT artifacts as instantiations of theoretical constructs." In a second step, one can evaluate whether the design is indeed effective in terms of, for instance, increased productivity at individual, group, or organizational levels if users capitalize on the action allowed through the artifact.

5.4. Comparison with Other Approaches in Formulating Design Principles

Heinrich and Schwabe [37] suggested that design principles should be structured to include value grounding (requirement), conceptual grounding (relationship between constructs and domain objects), explanatory grounding (explanation and justification), and prescriptive statement (formulation of action applicable in design).

Their proposition is intended to overcome the "lack of explication of either the maturity level of the type of knowledge contribution" [p. 153] of a previous formulation proposed by Van den Akker [38, p. 9]. Van den Akker recommended the following structure:

> if you want to design intervention X (for the purpose/function Y in context Z), then you are best advised to give that intervention the characteristics A, B, and C (substantive emphasis), and to do that via procedures K, L, and M (procedural emphasis), because of arguments P, Q, and R).

We would not say that these structures are ineffective, but they simply have not addressed the inconsistency challenge (Section 5.1) and formulation orientations (Section 4) found in design research practice. Our proposed formulation therefore contributes to these previous propositions in several ways.

First, our proposition is based on design research practice and previous formulations of design principles as reported in IS journals. The issues we address are therefore relevant to what we have been practicing as a discipline.

Second, we draw upon the concept of affordances recently used to signify the interrelationship between users and technologies [see 23, 39]. Additionally, we view design principles as a part of design theory [7], and not as a substitute. This is analogous to placing a magnifying lens over only the recipe section in a physics- and chemistry-based rendition of molecular gastronomy.

Third, our proposition puts forward the importance of defining the boundary conditions. Finally, it promises consistency, clarity, and concision.

At the same time our proposed formulation of design principles combines what have been referred to by Gregor and Jones [7] as "purpose and scope" (captured through *activity of user group* and *boundary conditions* in our formulation) and "principles of form and function" (captured through *material properties* in our formulation), or similarly, "meta-requirement" and "meta-design" [40]. In other words, it incorporates causa finalis (what for) and causa formalis (what makes an object that object), to borrow Aristotle's way of explaining things [cited in 7]. It may even include causa materialis (what constitutes an object). Design principles *being acted upon* by designers brings the artifact about (causa efficiens), this demonstrates the importance of actionability in formulating design principles. The comparison is presented in table 7.

Table 7: Our recommendation compared to existing frameworks

<table>
<tr><th>Aristotle</th><th>Gregor and Jones [7]</th><th>Walls, et al. [40, 41]</th><th>Our proposition</th></tr>
<tr><td>Causa finalis</td><td>Purpose and scope</td><td>Meta-requirement</td><td rowspan="3">Design Principle: action, materiality, and boundary conditions</td></tr>
<tr><td>Causa formalis</td><td>Principles of form and function</td><td>Meta-Design</td></tr>
<tr><td>Causa materialis</td><td>Constructs</td><td>-</td></tr>
<tr><td>Causa efficiens</td><td>Principles of implementation</td><td>Design method</td><td>Design principle being acted upon</td></tr>
</table>

6. Conclusions

We began this paper with two questions about (1) what different orientations there are in the formulation of design principles in the IS discipline and (2) what the characteristics of effective design principle formulation are. To that end, we collected, reviewed, and analyzed design principles in IS journals.

In this paper, we have focused on socio-technical design, that is, how IT/IS artifacts are used in *human* action. However, IT/IS artifacts can be used otherwise, for instance as part of an automated process. In this case, we also need materiality and action. However, in this case the technology is not perceived as affordance of action, but deterministically leads to certain consequence.

To answer the first question, we have identified three general orientations in the formulation of design principles used in top IS journals: action oriented design principles, materiality oriented design principles, and action and materiality oriented design principles. However, we have identified a lack of consistency and precision in some formulations and have therefore put forward a recommendation for improvement. We hope that our analysis contributes to the identification of design principles in the IS discipline as well as in other disciplines.

Our proposed effective formulation of design principles, which also answers the second question, is epitomized by a structure that describes which material property enables users to do what activity under what boundary conditions. The precision is increased by employing metaphors of human activity to denote what the artifact should enable and technical terms to denote what material properties should be built. We further argue that, in order to be generalizable, design principles should be formulated at an abstract level. A concrete formulation includes a predetermined set of instantiations, which leaves no room for any other instantiation. Naturally, the generalizability only applies to the extent that the different contexts share the boundary conditions defined by the design principle.

This paper also contributes to defining the role of design principles as a component part of full-blown design theory. It is an effectively formulated set of design principles that designers need, so that they know what to be designed and still have room for creativity. Further studies are required in order to improve the ideas presented in this paper. Firstly, we will test whether our proposed formulation of design principles is indeed more effective than other available formulations. Secondly, a further elaboration on the level (or levels) of abstraction is important, coupled with problems of decomposition of design principles. This will also include an elaboration of each unit of the design principle structure we have suggested in this paper. We also deem it necessary to delve deeper into the notion of “users” of design principles, which will provide us with insights about how to measure the quality of a design principle. Finally, we will provide a more encompassing view of design principles considering both human and non-human users of IT/IS artifacts.

It is expected that the desired outcomes will result from an evolving and accumulative process of forming a prescriptive body of knowledge on the design of IS/IT artifacts [2]. Nevertheless, it will be interesting to see how we, as a discipline, adopt standards of formulating prescriptive knowledge in our editorial processes. We hope that, through our work, we contribute to this important process.

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Appendix: Terminology

Some readers may interpret action-oriented design principle as equivalent to principles of function, whilst materiality oriented principles correspond with principles of form.

However, our analysis suggests that, indeed, function and form are properties of the technology, that is, properties of the material aspect of what we design. This materiality then affords human action, or is intended to afford human action. The concept of “afforded user action” differs in important ways from the terms “primary function” or “goal” that might be used in cases where the technology can act independently of the user. Here is a simple example:

- A house—in order to be a house—has walls and a roof (principles of form)
- A house typically has a door that can be opened and closed (principle of function)
- A house with these principles of form and function affords humans to go in and out (action)

Against this background, principles of form and function relate to the materiality and proffer certain action potentials for humans.