Antunes, P., Thuan, N., & Johnstone, D. (2022). Nature and Purpose of Visual Artifacts in Design Science Research. Information Systems and E-Business Management. https://doi.org/10.1007/s10257-022-00559-2

Nature and Purpose of Visual Artifacts in Design Science Research

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Abstract

Design science is a recognized information systems research paradigm, which is fundamentally centered on problem solving through technology design. Design science is usually supported by a variety of visual artifacts, which help make sense of the research process and communicate the final insights. In this study, we analyze the nature and purpose of such visual artifacts. We adopt semiotics and a theory of visualization of thought, in combination with a literature review, to elaborate a framework of design science visual artifacts. We consider three domains of analysis: intentionality, form-and-function, and visual scheme. We demonstrate the applicability of the framework using two examples. Finally, we define a set of properties that researchers should consider when creating and using visual artifacts in design science: transparency of the relationship between representation and object, self-sufficiency of the visual artifact, and consistency of communication. The proposed framework helps design science researchers understand what properties should be focused on when developing their visual artifacts.

Keywords: Visual Artifacts, Design Science, Design Science Research, Visualization of Thought.

1 Introduction

Researchers in Information Systems (IS) often develop visual artifacts to represent some elements of their research, such as conceptual frameworks, requirements, IS components, architectures, data models, design processes, and others. Such artifacts can be discussed using Charles Sanders Peirce's philosophy, considering in particular his triadic notion of sign (the visual artifact) as something that stands for something else called object and which helps interpret that object (Beynon-Davies, 2018).

Four fundamental arguments support the use of visual artifacts in research. First, they convey subjective knowledge, in the form of perceptions, ideas and thoughts, which result from the contemplation of objects, and which contribute by generating objective knowledge about the world (Popper, 1979; Varghese, 2019). Second, visual artifacts are essential for structured inquiry and exploration, generating emerging knowledge through action, in the form of reflective thinking or "conversations with the materials at hand" (Schön, 1983; Schön & Wiggins, 1992). Third, visual artifacts provide a medium for investigating the research process, which is about how visual artifacts themselves can be used to accomplish scientific goals (Ghajargar & Wiberg, 2018). Finally, visual artifacts are also a supporting device for telling a "good story" about the research, articulating the conflict, setting, plot, and findings (Shepherd & Suddaby, 2017).

In addition to these general considerations, the use of visual artifacts seems even more useful in IS and design science (Hevner et al., 2004). Design science is a recognized IS paradigm, which is fundamentally centered on problem solving through technology design (Gregor & Hevner, 2011). Design science is specifically concerned with the creation of innovative IS artifacts, which can have some degree of abstraction (Gregor & Hevner, 2013; Weigand et al., 2021). That is, creating a visual artifact may even be the primary purpose of a design science study. As noted by Alter (2015, p. 48), the IS artifact extends beyond an "entity consisting of hardware and software" towards "anything that an IS researcher might be interested in". Furthermore, the method and process of design are also relevant to design science; and visual artifacts can be useful in communicating about the problematization, design, evaluation, and use of IS artifacts (Baskerville, Baiyere, et al., 2018; Gregor & Jones, 2007).

In design science, visual artifacts are often regarded as passive research tools, which help communication (Ghajargar & Wiberg, 2018). However, they also play an active role in reflection: as the researcher establishes a conversation with the artifact, the artifact is not only a repository of 'working' knowledge, but also an agent for connecting existing and emerging knowledge (Shepherd & Suddaby, 2017).

A paradigmatic example is the well-known 'information systems research framework' developed by Hevner et al. (2004, p. 80). This visual artifact is notable in showing the articulation between the cycles of design, rigor and relevance, which underlies the design science research paradigm. Hevner's et al. (2004) visual artifact enacts our interpretations and discussions about design science, as much as other notable visual artifacts enact interpretations in other fields, such as Nonaka and Takeuchi's (1995) SECI model in knowledge management, and Zachman's (1987) framework in software development. All in all, even though the common saying is that "the map is not the territory", in fact, our interpretation of reality is recursively shaped by visual artifacts (Siegert, 2011).

However, we could not find published research into the nature and roles of visual artifacts in design science. Research into the nature and roles of visual artifacts may help researchers communicate important aspects of their research (Langley & Ravasi, 2019). Furthermore, as seen in computer science, IS and other fields, advancing the study of unique, purpose-built visual artifacts may also contribute to reflection on design science methodologies, processes and tools.

Addressing these general objectives, in this study we pursue three goals. First, we develop a framework characterizing design science visual artifacts. The framework is based on semiotics and a theory of visualization of thought and is further developed by a literature review on the use of design science visual artifacts. Second, we demonstrate the application of the framework using examples. Finally, we define a set of properties of design science visual artifacts.

The paper proceeds as follows. In the next section, we discuss the related research. In Section three, we outline our research approach. In Section four, we develop our framework, which, based on theory of visualization of thought, addresses three fundamental dimensions: intentionality, form-and-function, and visual scheme. Section five applies the framework to review a sample of visual artifacts from the design science literature. In Section six, we demonstrate the application of the framework by analyzing two recently published visual artifacts. In Section seven, we discuss three properties emerging from this study (transparency, self-sufficiency and consistency), which help the research community consolidate the use of these artifacts. We end the paper with some concluding remarks.

2 Related Research

The focus on visual artifacts in the IS domain has been highlighted by several interrelated research streams, which we discuss below.

Semiotics. As noted earlier, Peirce's semiotics establishes a triadic conception of sign use, which must be understood in relation to object and human inquiry (Beynon-Davies, 2018). A characterization of visual artifacts as signs involves realizing that the artifact exists in the material world, as a representation of an object in the factual world, which is external and independent of the representation, but it also depends on the social world, as individuals enact their own interpretations about the artifact and object (Mingers & Willcocks, 2014).

This triadic conception has had a profound impact on the IS field, notably regarding the development and use of technology by organizations (Mingers & Willcocks, 2014, 2017), development of technology for representing knowledge processed by IS (Friedman & Thellefsen, 2011), formation of representations when humans interact with IS (Brödner, 2019), and theorizing about IS phenomena (Grover & Lyytinen, 2015). In regard to design science, besides the relevance of representation in problem solving, the development of meta-representations is also an essential aspect of the design process, as they support meta-design, i.e., design solutions capable of handling classes of problems rather than just solving singular problems (Iivari, 2020).

The consideration of semiotics as a foundation for visual artifacts seems almost an inevitability, as it provides ontological and philosophical underpinnings for the research streams discussed below.

IS representation theory. According to IS representation theory, an IS aims to provide a faithful representation of a real-world phenomenon, from the viewpoint of its creators (Burton-Jones et al., 2017; Recker et al., 2019). To accomplish this purpose, the IS uses symbols that stand for, or model, the focal phenomenon (Burton-Jones et al., 2017). The model user is expected to articulate their interpretation of the focal phenomenon. However, as noted by

Burton-Jones et al. (2017, p. 1309), representation theory "does not use any particular theory of meaning […] to explain how users develop or articulate their perception of meaning".

The adoption of representation theory as a conceptual foundation for design science visual artifacts seems limiting for two major reasons. The first reason is that representation theory does not explain how to communicate meaning through visual artifacts. The second reason is that representation theory aims to provide accurate and complete IS representations (Burton-Jones et al., 2017), while design science is broader in scope, covering human creation and associated tasks, situations and IS artifacts (March & Smith, 1995). In other words, a visual artifact can, but does not have to, comply with representation theory; it can, but does not necessarily have to, be a model.

Conceptual modeling. Conceptual modeling has a long tradition in the IS field, which concerns the development of models representing the static and dynamic aspects of an IS (e.g., requirements, properties, events, states, and processes) (Wand & Weber, 1990, 2002) and related tasks (e.g., development, evaluation and use) (Allen & March, 2012). Research on IS models has mainly focused on the development of conceptual modeling grammars and processes, which provide ontological expressiveness and clarity, in order to avoid deficient or equivocal representations and poor IS developments (Allen & March, 2012; Becker et al., 2014; Bera et al., 2014; Wand & Weber, 2002).

The adoption of conceptual modelling as a foundation for design science visual artifacts establishes a dependence on formalisms, regularities and methods required by IS development (McKinney Jr & Yoos, 2010; Wyssusek, 2006). However, design science is broader in scope than IS development, as it relates design with research (Baskerville et al., 2011), concerns more diverse artifacts (e.g., design principles, processes and methods) (Goldkuhl, 2013; Gregor & Hevner, 2013), utilizes and generates a wider variety of knowledge related to artifact construction (e.g., working knowledge) (Iivari, 2020), and establishes more intricate relationships between artifacts, people, organizations, and technology (Hevner et al., 2004).

Cognitive theory. A visual artifact is also a visual expression of thought by the designer, which combines text and other visual elements to activate significant aspects of meaning through cognitive mechanisms (Goel, 1995; Tversky, 2014). Unlike conceptual models, which rely on domain-specific symbols, notations and grammars for readers to understand what is represented, cognitive theory relies on universally known or knowable elements to make sense of objects (Evermann, 2005; Langley & Ravasi, 2019).

Researchers have been investigating the cognitive dimensions of notations used in the creation of IS artifacts (Blackwell et al., 2001). An understanding of these dimensions helps predict their impacts on the readers, e.g., regarding the interpretation of complex information structures (Green, 1989). Such predictions help formalize an intention behind a visual artifact, even though the visual artifact supports an informal representation of the object (Blackwell et al., 2008).

An important characteristic of visual artifacts in design science is that they support communication about the output and process of design (Walls et al., 1992). As such, cognitive theory centered on the visualization of thought seem particularly pertinent to make sense of design science visual artifacts (Evermann, 2005; Nickerson et al., 2013; Tversky, 2014). Furthermore, “design is a quintessential cognitive task” (Goel & Pirolli, 1992), and therefore there is strong alignment between creating visual artifacts and conducting design. Finally, the unstructuredness of design also aligns well with a more informal approach to representation than suggested by IS representation theory and conceptual modeling.

3 Research Approach

Our study is organized in five steps (Figure 1). The first step is the creation of a conceptual framework. This framework informs the development of a preliminary classification scheme for design science visual artifacts.

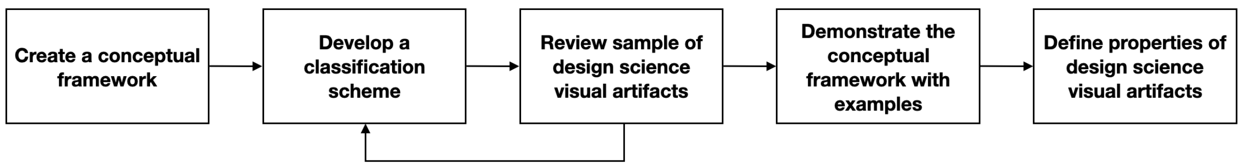


Figure 1. Research approach

Using the framework and classification scheme, we then explore the literature containing design science visual artifacts using a descriptive review (Paré et al., 2015). Descriptive literature reviews “seek to determine the extent to which a body of empirical studies in a specific research area supports or reveals any interpretable patterns or trends with respect to pre-existing propositions, theories, methodologies or findings” (Paré et al., 2015, p. 186). Using a preconceived classification scheme contributes to increase the systematicity of the review by clearly identifying the elements of interest and underlying exploration strategy (Paré et al., 2016). Especially when exploring the literature, having such a scheme helps to delimit and focus the analytic process (Miles et al., 2014).

In parallel with the characterization of main patterns and trends related to the use of visual artifacts, we consolidate the classification scheme. Then, we demonstrate the use of the framework with two examples taken from the literature. These exercises show how to use the proposed framework to examine the nature and purpose of design science visual artifacts, and to identify and resolve issues with the use of these artifacts. Demonstration is an important activity in design science methodology, which can be used as a proof of concept for the proposed approach (Peffers et al., 2007).

Finally, through reflection, we draw some implications of this study for research practice. This is done by identifying a set of fundamental properties of design science visual artifacts.

4 Framework

We adopt the theoretical perspective of visualization of thought proposed by Goel (1995)[1] as a conceptual foundation for researching design science visual artifacts. This theoretical perspective adopts Peirce’s triadic

[1] Goel explicitly states that he has not proposed a theory, but a theoretical perspective compatible with different theories over visualization of thought (Goel, 1995, p. 24).

conception of sign use where the artifact exists in the material world as a representation of an object that exists in the factual world. The artifact seeks to organize knowledge about the object. To achieve this goal, the artifact requires an activity that links mind, artifact and object.

In our research, we focus on the object in the world as design science research, regarding design science as a real-world phenomenon, which generates design science outputs (solution artifacts) through design science processes (March & Smith, 1995). We consider that design science researchers create visual artifacts to represent design science, to help them with their research. This is done by selecting and organizing certain attributes of their research.

We note that other minds may be involved as well, when a subsequent intention might be to communicate the research, using design science visual artifacts to build certain interpretations and significations about both the design science outputs and processes in the readers' minds, so they may appreciate the research contributions and, in some cases, go on to use, extend, or modify the research contributions with further research.

Goel (1995, p. 19) proposes that the creation of the visual artifact is driven by intentionality: the visual artifact seeks to enact a specific interpretation. Without intentionality, the interpretation would be serendipitous and potentially useless. Intentionality is particularly relevant in design science, where researchers seek to develop specific interpretations, which explain the research and help the IS community take benefits from such research. In other domains, such as when experiencing art, intentionality may not be the main driver of a visual artifact.

Besides intentionality, Goel (1995, pp. 22–23) regards the visual artifact in two other domains: realm and scheme. The realm domain defines the form-and-function of the artifact, which enacts an intended interpretation of the object in the world. Form-and-function involves linking the visual elements in the visual artifact to objects in the world, and organizing the visual elements using perceptible patterns (Blackwell & Richards, 2019). Example patterns include flowcharts and cause-effect diagrams. Conferring adequate form-and-function to the visual artifact is essential to enact the intended interpretation; and understanding form-and-function is an important cognitive activity associated to reading a visual artifact (Blackwell et al., 2001). Finally, the scheme domain helps make sense of the visual artifact using recognizable visual tokens. For instance, visual tokens like boxes and arrows can help recognize steps and order in a visual artifact (Blackwell & Richards, 2019).

This theoretical view suggests that researchers should consider three dimensions of enquiry when creating a design science visual artifact: intentionality, form-and-function and visual scheme. These three dimensions combine to help readers make sense of a design science study.

A logical consideration of these three domains suggests taking a stepwise approach to the creation of design science visual artifacts. Understanding the underlying intentionality emerges as the first logical step in characterizing the artifact, as it defines its main purpose. This leads to a typology of design science visual artifacts that essentially differentiates what researchers intend to communicate.

The second logical step concerns the realm domain, where researchers confer a specific form-and-function to the artifact. This involves defining a set of visual elements and patterns that allow readers to understand the relationships between the artifact and the represented aspects of research. The rationale for considering form-and-function after intentionality is of logical consequence: the researcher, after deciding which intentionality to assign to an artifact, should decide how to make it work by conferring a specific form-and-function.

The third and final step is intended to help readers recognize the communicated thoughts by ascribing a recognizable visual scheme to the artifact. This involves the use of recognizable visual tokens such as symbols, characters, words, lines, and arrows.

In Figure 2, we present our framework, which adopts visualization of thought as a theoretical perspective, and applies it to design science visual artifacts. This framework provides a foundation for analyzing visual artifacts in a stepwise way, starting with intentionality, then considering form-and-function, and finally addressing visual scheme. In the next section, we apply this framework to review existing design science visual artifacts.

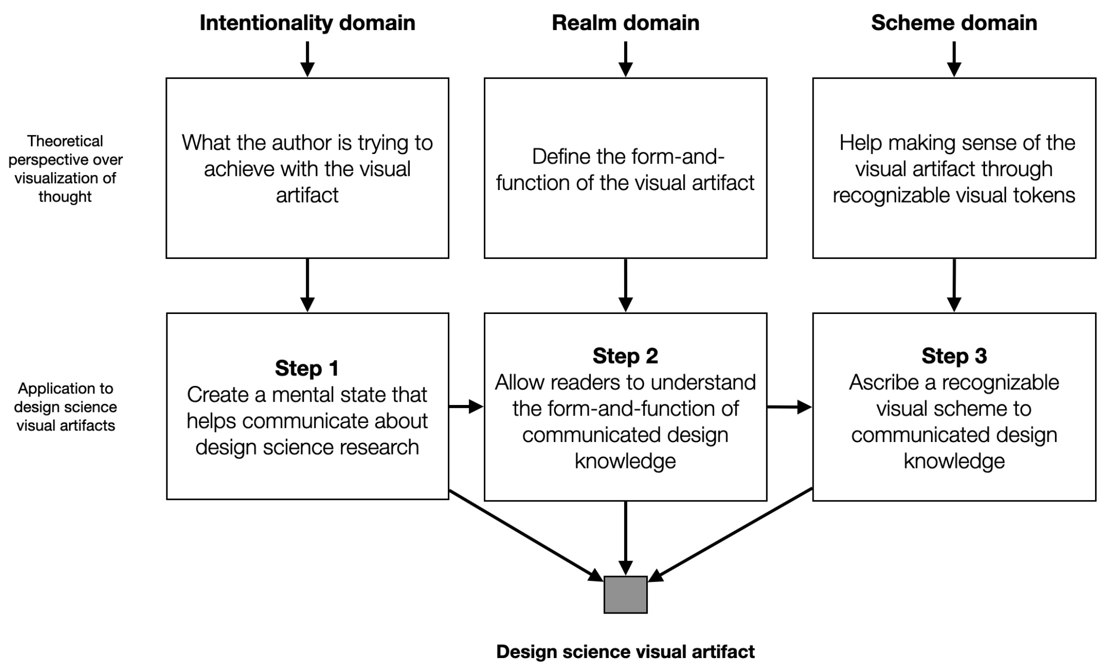


Figure 2. Framework of design science visual artifacts

5 Review and Classification Scheme

5.1 Review method

The review follows the three main steps suggested by our framework, considering intentionality, form-and-function, and visual scheme. Following recommendations regarding systematicity in conducting literature reviews, the adopted procedure comprises several stages (Paré et al., 2016): 1) identify and select relevant papers; 2) extract data from selected parts of each paper; and 3) synthesize the review results. These stages are detailed below.

Identifying and selecting relevant papers. In the first stage, we identified papers in the design science domain that propose and use visual artifacts. The search was restricted to papers published since 2004, when Hevner's et al. (2004) influential paper on design science research was published in MIS Quarterly. Even though we recognize early developments (e.g., March & Smith, 1995; Nunamaker et al., 1990; Walls et al., 1992), the maturity of the design science domain is associated with this important milestone.

For targeting the literature, we selected one source, the Association for Information Systems (AIS) Senior Scholars' Basket of Journals, which covers eight of the top journals in the IS field. We regard this group as representative of the most mature artifacts.

We searched the Scopus database, which indexes all these sources, using the following keywords: 'design science' and ('framework', 'model' and 'diagram'). These keywords were selected because they have a generic scope and are widely used in the design science literature.

As inclusion criteria, the selected papers would have to present, describe and use at least one design science visual artifact; and the artifact should be used to communicate about the research. After conducting the search on Scopus and applying the inclusion criteria, the selection totalized 68 papers.

Extracting data. To extract data from the selected papers in a systematic way, we developed a coding sheet that considered our initial classification and adapted it to reflect what we found in the literature. To ensure the inter-coder reliability, we used two coders. Both coders independently conducted the coding procedure and differences were discussed until a consensus was reached. This procedure generated multiple adjustments to the classification scheme. In particular, the classification of 'form' required significant discussion, as, for instance, different linear forms were identified by coders (e.g., phases, steps, activities, and timelines). The reached consensus required abstracting all these variations.

While extracting data, we kept our minds open for new codes in order to explore different usages and characteristics of design science visual artifacts. Multiple data extraction and coding cycles were necessary to consolidate the final classification scheme. Codes that generated equivocal and conflicting views were either clarified or rejected; and we also focused on providing increasingly clear and parsimonious concepts. For instance, our initial classification of visual scheme considered that artifacts could have multiple schematizations, but we finally moved towards an understanding that is closer to Goel's intention, which is to broadly understand why a symbolic system serves a certain cognitive function (Goel, 1995, p. 138), thus resulting in a classification of schematization that regards the whole artefact.

Synthesis. The review finished with an appreciation of how the framework and classification scheme fit the uses of design science visual artifacts by researchers. In this process, besides reflection, we also used descriptive statistics of the coding dimensions as an indication of the relevance and adequacy of the classification dimensions in explaining the nature and purpose of design science visual artifacts. Next, we present the results, considering intentionality, form-and-function, and visual scheme.

5.2 Intentionality

We found two dimensions of intentionality in the reviewed artifacts, which relate to research contexts and research roles. In relation to research contexts, we identified two categories:

Sensemaking. The artifact is used to communicate about certain aspects of the research (Langley & Ravasi, 2019; Ravasi, 2017). The artifact contributes towards consolidating certain aspects of the research narrative, for instance, synthesizing prior knowledge related to a design science study, and describing an adopted design process (Shepherd & Suddaby, 2017).

Conceptual output. The artifact is used as a conceptual output, which communicates final insights about the research (Langley & Ravasi, 2019). The artifact provides an opportunity to put concepts together, contributing emerging design knowledge (e.g., a new conceptual framework, or a new design), which can be contrasted with prior knowledge (Shepherd & Suddaby, 2017).

In relation to research roles, we identified four categories:

Organizing. The artifact is used to provide key insights about the conduct of design science research, with a focus on rigor. These artifacts describe research methods, processes, activities, and components, and their relationships (e.g., Baskerville & Myers, 2015, p. 32; Peffers et al., 2007, p. 54).

Mapping. The artifact is used to map the existing knowledge related to a study. An artifact in this category usually results from the process of reviewing the scientific literature and provides a synthesis of the main elements of interest and associated concepts and relationships (e.g., Roussinov & Chau, 2008, p. 176).

Scaffolding. The artifact is used to scaffold the design of other IS artifacts. This is done by identifying a set of design dimensions, elements, variables, influences, and expected outcomes (e.g., Choi et al., 2010, p. 263).

We further identified three sub-categories related to scaffolding. One sub-category considers artifacts that characterize or even establish a particular theory. This is done by proposing a narrative setting and identifying a set of core constructs (e.g., Beynon-Davies, 2018).

Another sub-category considers artifacts that do not characterize or establish a theory, but instead refer to theorizing by providing a theoretical lens (Niederman & March, 2019). The notion of theorizing is broader in scope than theory, as a theoretical lens can articulate different types of meaning, including definitions, dimensions, descriptions, and explanations (e.g., Baskerville et al., 2015, p. 550). Some consider theorizing as a form of pre-theory, which contributes formative explanations, instead of theoretical propositions (Baskerville & Vaishnavi, 2016; Gregor & Hevner, 2013; Nunamaker et al., 1990).

The third sub-category is related to kernel theory (Gregor & Jones, 2007). The main goal of kernel theory is to transfer knowledge from other domains, usually natural and social sciences, into a design science study. This is accomplished by establishing links to existing theories and providing justificatory knowledge supporting a design (e.g., Oetzel & Spiekermann, 2014, p. 129).

Designing. The artifact is used to explain the essential elements of a design. This is done by articulating the problem and solution, and characterizing the main design components and their relationships (e.g., Abbasi et al., 2012, p. 1303).

In this category, we identified three sub-categories, which reflect distinct conceptions of design as a product, a process or both (Walls et al., 1992). From a product perspective, the intentionality of the artifact is explaining the core components of something to be done (e.g., Astor et al., 2013, p. 256). From a process perspective, the intentionality of an artifact is explaining the constructs and methods that enabled the design (e.g., Pries-Heje & Baskerville, 2008). Since design concerns both the product and process of design, it is natural that an artifact may express both concerns (e.g., W. Kuechler & Vaishnavi, 2012, p. 399).

Table 1. Intentionality – research contexts

Dimension	Categories	n=68	%	
Intentionality – research contexts	Conceptual output	41	60.3%	
	Sensemaking	27	39.7%	100%

In Table 1, we summarize our review regarding the research context dimension of intentionality. The results show that conceptual outputs prevail, which suggests that most visual artifacts have been used to communicate the final insights of design science research. Regardless, Table 1 shows a good number of artifacts that contribute to sensemaking. We regard sensemaking as important to articulate and communicate about design science research, as it entangles meaning with visual means (Boxenbaum et al., 2018).

Table 2. Intentionality – research roles

Dimension	Categories	n=68	%	
Intentionality – research roles	Designing	28	41.2%	
	Organizing	21	30.9%	
	Scaffolding	11	16.2%	
	Mapping	8	11.8%	100%

In Table 2, we summarize our review regarding the research roles dimension of intentionality. The results show that designing is the most prevalent intentionality in the dataset, followed by organizing. The scaffolding and mapping categories emerge as much less prevalent than the other two categories. Even though we did not conceive the four categories of the intentionality dimension as exclusive, we did not find any artifact covering multiple categories.

Table 3. Intentionality – research roles versus research context

Intentionality		Research contexts		
		Sensemaking	Conceptual output	
Research roles	Designing	4 (5.9%)	24 (35.3%)	
	Organizing	12 (17.6%)	9 (13.2%)	
	Scaffolding	4 (5.9%)	7 (10.3%)	
	Mapping	7 (10.3%)	1 (1.5%)	100%

In Table 3, we provide an integrated view of the two dimensions of intentionality. Unsurprisingly, designing conceptual outputs takes a clear lead. However, what we find most interesting are the combinations of roles and contexts covered by design science visual artifacts. In particular, we observe that design science researchers contribute conceptual outputs in relation to all research roles, not only designing; and also seek to make sense of their research in relation to all research roles, including designing.

Table 4. Designing sub-categories

Category	Sub-categories	n=28	%	
Designing	Product	19	67.9%	
	Both (product and process)	6	21.4%	
	Process	3	10.7%	100%

Table 5. Scaffolding sub-categories

Category	Sub-categories	n=10	%	
Scaffolding	Theorizing	6	60.0%	
	Theory	3	30.0%	
	Kernel theory	1	10.0%	100%

Table 4 summarizes the distribution of artifacts in the designing category and according to the three identified sub-categories. The results show that the product category is significantly more popular than the other sub-categories. Finally, Table 5 presents our further analysis of artifacts in the scaffolding category and according to the three identified sub-categories. Even though the number of scaffolding artifacts is small, we found that the theorizing sub-category takes the lead over the theory and kernel theory sub-categories.

5.3 Form-and-function

As noted earlier, form-and-function is conferred by visual elements and patterns that allow readers to understand the relationships between the research and the represented design knowledge. We identified three patterns in the dataset related to form.

Linear. Artifacts in this category relate concepts using linear patterns, which in general have well-defined starting and finishing points. Examples include timelines, sequences of steps, phases or activities, development stages, chains of events, and processes (e.g., Peffers et al., 2007, p. 54).

Loosely relational. Artifacts in this category connect concepts using non-linear, loosely coupled patterns, which may denote separation and hierarchy of concepts using one or more focal points. Examples include taxonomies, typologies and collections (e.g., Baskerville et al., 2015, p. 550; Baskerville, Baiyere, et al., 2018, p. 363). Sometimes the relationships are not made explicit and have to be inferred by the reader considering, e.g., proximity and center-outward organizations (Tversky, 2014).

Tightly relational. Artifacts in this category connect concepts using tightly-coupled relationships, which enact a system of concepts with many interrelated dependencies (Meredith, 1993). Examples include graphs and object or component systems (e.g., Hevner et al., 2004, p. 80).

We also identified three patterns in the dataset related to function, which use different ways to express the research elements in terms of causes and effects:

Dimensional. The dimensional pattern categorizes and organizes the research elements using temporal, spatial or categorical dimensions (e.g., Pries-Heje & Baskerville, 2008, p. 734).

Domain. The domain pattern categorizes and structures the research elements according to affinity or adherence to specific domains (e.g., Hevner et al., 2004, p. 80).

Influence. This pattern characterizes the influences between research elements, which may include strength and extent (e.g., Gregor et al., 2014, p. 658).

Table 6. Form-and-function

Dimension	**Categories**	**n=68**	**%**	
Form	Loosely relational	29	42.6%	
	Linear	24	35.3%	
	Tightly relational	15	22.1%	100%
Function	Influence	43	63.2%	
	Domain	21	30.9%	
	Dimensional	4	5.9%	100%

In Table 6, we summarize our review regarding form-and-function. We observe that a majority of artifacts take lightweight forms, using either loosely relational or linear patterns. As for function, the strong majority of artifacts in the dataset are focused on expressing influences, followed by domain relationships.

5.4 Visual scheme

The third and final step to characterize artifacts concerns visual scheme. Here, we consider the overall schematization adopted by artifacts (Goel, 1995, p. 180), as well as the main characteristics of concept and relationship tokens (see Appendix A for details). We focus on concept and relationship tokens because we regard them as fundamental to visually express design knowledge in a visual artifact. They can serve as focal points from where to start making sense of the objects in the world (Klein et al., 2006). However, in other contexts, a visual artifact may consider other types of visual tokens, such as spaces, shapes and spatial relations (Suwa & Tversky, 1997; Tversky, 2014).

Regarding the overall schematization, we found the following types in the dataset:

Notational. Adoption of a symbolic visual system, which systematically integrates text and recognizable visual tokens such as lines, arrows and boxes (e.g., Baskerville et al., 2015, p. 550).

Discursive. The use of natural language to convey meaning, usually in combination with few visual tokens, such as bullet points (e.g., Baskerville, Kaul, et al., 2018, p. 141).

Sketched. The use of non-notational visual tokens to convey meaning, which incorporate ambiguity in interpretation. Examples include the use of doodles to suggest concepts and ideas, and the use of arrows to suggest associations, but without committing to a specific type of association (e.g., Venable et al., 2016, p. 80).

Table 7. Visual scheme

Dimension	Categories	n=68	%	
Schematization	Notational	54	79.4%	
	Sketched	7	10.3%	
	Discursive	7	10.3%	100%
Concept tokens	Items	56	82.4%	
	Groups	31	45.6%	
	Classes	9	13.2%	141%
Relationship tokens	Influences	42	61.8%	
	Associations	26	38.2%	
	Implicit	13	19.1%	
	Mutual influences	8	11.8%	130%

Note: An artifact may have multiple types of concept and relationship tokens, which result in overall percentages above 100%.

Table 7 summarizes our review regarding schematization. Notational schemes are strongly dominant, while discursive and sketched schemes are not popular, as few artifacts enact interpretations of research in these ways.

Further detailing the visual scheme, we found the following types of concept tokens in the dataset:

Items. Singular visual tokens used to denote uniqueness or distinctiveness (e.g., Pries-Heje & Baskerville, 2008, p. 734).

Groups. Collections of visual tokens grouped to denote affinity, for example using bulleted lists and containers (e.g., Hevner et al., 2004, p. 80).

Classes. Collections of visual tokens grouped to suggest composition or configuration (e.g., Hevner et al., 2004, p. 80).

We also found the following types of relationship tokens in the dataset:

Implicit. These relationship tokens are not explicit but can be established by context (e.g., Pries-Heje & Baskerville, 2008, p. 734).

Associations. The use of directed, non-directed and typed connections expressing structural relationships between concept tokens (e.g., B. Kuechler & Vaishnavi, 2008, p. 492).

Influences. When directed, cause-effect connections are used between concept tokens (e.g., Hevner et al., 2004, p. 80).

Mutual influences. When bi-directional, cause-effect connections between concept tokens are used (e.g., Gregor & Jones, 2007, p. 321).

Considering the use of concept tokens in our dataset, we observe that groups prevail over classes. Regarding relationship tokens, even though influences make up the majority, we also found many associations in the dataset.

Overall, the detailed classification scheme using intentionality, form-and-function and visual scheme allows us to characterize artifacts with significant detail (Figure 3). On the one hand, all these elements may over-complicate the characterization of an artifact. On the other hand, they can be used to (a) provide an insightful understanding of artifacts, as demonstrated in section 6; and (b) provide a framework with specific options to guide, but not constrain, the use of these important artifacts, as discussed in section 7.

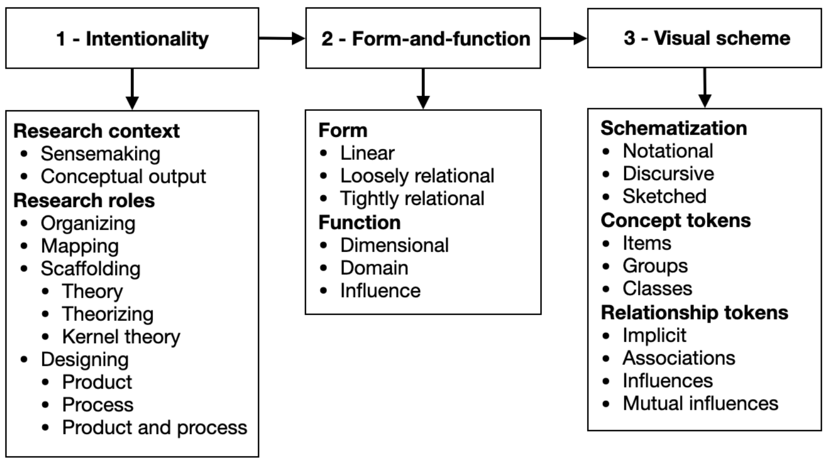


Figure 3. Classification scheme of design science visual artifacts

Our analysis of frequencies of occurrence of the various categories provides important insights about what types of artifacts researchers have been developing. Considering all elements together, we summarize the following characteristics:

- Ability to make sense of the research and to communicate the final insights of the research, even though the latter is more prevalent.
- Ability to support a diversity of roles, which cover almost all stages of research, from positioning the research (mapping and scaffolding) to planning the research (organizing) and conducting the research (designing), even though the latter stage is more prevalent.
- Diversity of research contexts and roles, even though designing conceptual outputs is dominant.
- Preference for lightweight conceptualizations, in particular adopting loosely related and linear forms, rather than more complex and strict conceptualizations.
- Privileging notational visual schemes, with a prevalence of isolated items and groups, which are predominantly related through influences.

These characteristics suggest that design science visual artifacts are significantly different from visual artifacts used in other IS paradigms, e.g., behavioral paradigm, which tend to define, relate and structure knowledge in more focused and tighter ways (Recker et al., 2019). The most prevalent types of notational visual schemes also indicate that design science brings distinctive competencies to the IS development tool set, in particular regarding analysis and design, which traditionally promote faithful IS representations (Recker et al., 2019). These characteristics contribute to position design science as a distinct IS research paradigm. They are relevant for the design science community to develop their own theories—about how they think and work—rather than depending on others' worldviews and bodies of knowledge (Galle, 2008).

6 Using the Framework

To demonstrate the use of the proposed framework, we analyze two examples of published design science visual artifacts. The examples were selected considering the quality of the articles and publication outlets, and the diversity of the artifacts. Any issues or concerns with the examples are not related with the quality of the underlying research. The single purpose of this exercise is to highlight the capacity of the framework to support an analysis of how visual artifacts relate to the underlying research.

6.1 Example 1 - Vom Brocke's et al. (2020) 'model of design knowledge'

In a recent editorial article, Vom Brocke et al. (2020) discuss how to accumulate design knowledge (DK) to extend the projectability of design science studies. In the abstract, the authors indicate that the article proposes three visual artifacts, including two models and one map. In the following, we discuss the first artifact, which is designated 'model of design knowledge' in the article and, for simplicity, referred to here as 'model' (Vom Brocke et al., 2020, Figure 1). The artifact is reproduced in Figure 4.

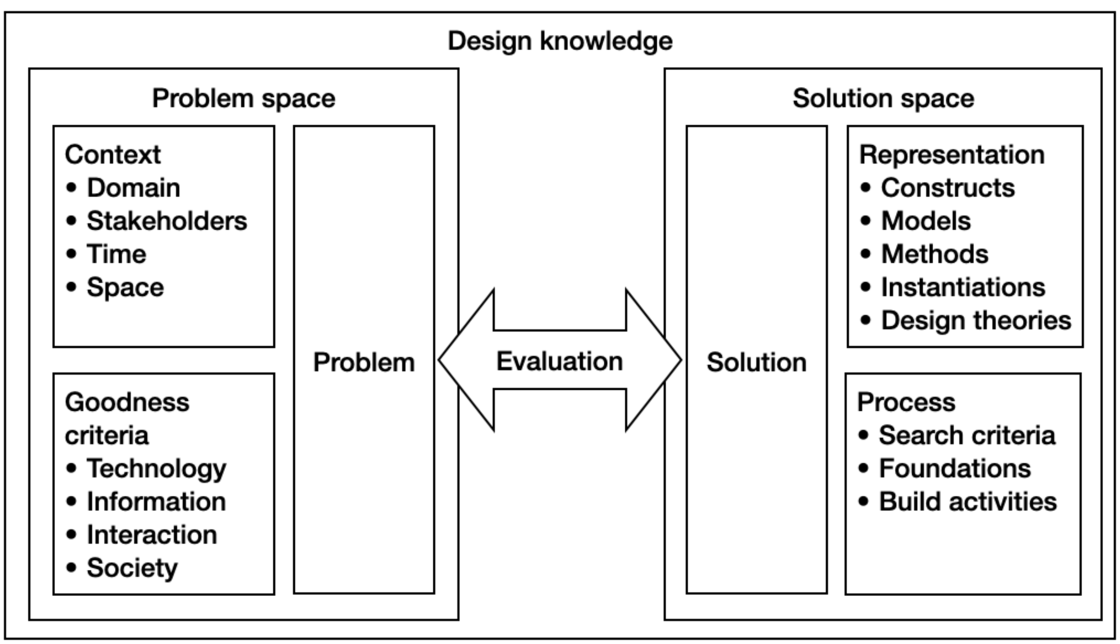


Figure 4. Vom Brocke's et al. (2020) model of design knowledge

Relationships between artifact, object and interpretation: The model is intended to convey an understanding of prescriptive DK. Prescriptive DK represents knowledge in the factual world regarding how IS artifacts are designed. The represented prescriptive knowledge contributes to the "practice of solving real-world problems", and also to rigor in advancing design science (Vom Brocke et al., 2020).

Prescriptive knowledge has several attributes, for instance, relating real-world problems or challenges to solutions. The authors also identify several components of DK, in particular the problem and solution spaces, and the evaluation component. These components, as well as their relationships, are organized by the model.

Intentionality: The research context concerns a conceptual output, which explains how to generate DK. The authors note that a DSR project can be multifaceted, and the proposed model helps putting together a set of basic components of DK. The authors indicate their intention is "to develop approaches and models to better position DK contributions to support knowledge accumulation and evolution". This statement suggests that the main goal of the visual artifact is designing an approach for contributing DK.

The authors also note: "[w]e consider these three components to constitute DK: Problem Space, Solution Space, and Evaluation". By denoting the constitutive components of the model, the authors indicate that DK contributions should be viewed more as a product than a process. For instance, the problem space is characterized as having three sub-components: problem, context and goodness criteria. The model does not include insights about the process of generating these components and sub-components.

Form-and-function: The model has one core component (DK) and several sub-components (e.g., the solution space is divided into representation and process). There are several relationships, including structural (e.g., the problem space is divided between problem, context and goodness criteria), hierarchical (e.g., design knowledge encompasses the problem and solution spaces), and relational (e.g., evaluation links to the problem and solution). Pondering the small number of relationships, the form is loosely relational.

The model's function is of type 'domain', as it categorizes the different domains of DK. Even though the problem and solution spaces are related using the evaluation concept, and visually that relationship takes the central stage, the domain effect predominates. Nevertheless, a different visual representation of the evaluation component and its relationships could contribute to reinforce the interpretation that the model's effect is domain.

Visual scheme: The model is sketched, as no particular conventions are adopted, and hierarchies and other types of relationships must be inferred by the readers. For instance, both rounded and right-angled boxes are used to denote hierarchy. The distinctions between rounded and right-angled boxes are unclear. Also, the rounded boxes surrounding the 'problem space' and 'solution space' names create some ambiguity, as they seem more decorations than visual mechanisms denoting items, groups or classes.

Another concern with the model's visual scheme is that, even though the textual description provided by the authors regards evaluation as a component, the way that specific visual token is presented suggests it is a relationship rather than a component. This may create a cognitive dissonance between reading the text and interpreting the model.

Finally, we note that the relationships between solution, representation and process are implicit. The same occurs with the relationships between problem, context and goodness criteria.

6.2 Example 2 - Mullarkey and Hevner's (2019) 'the elaborated action design research cycle'

Mullarkey and Hevner (2019) reflect on a research project, which adopted the action design research approach (ADR) (Sein et al., 2011), and elaborate a more flexible and detailed approach to ADR. The article includes several visual artifacts. The first artifact proposes an ADR cycle, which provides a more linear, and more detailed, characterization of ADR interventions. The ADR cycle then serves as foundation for the remaining artifacts, which characterize ADR research processes as multiple iterations of the ADR cycle. In the following we discuss the first artifact, designated 'the elaborated action design research cycle' in the article (Mullarkey & Hevner, 2019, Figure 1) and, for simplicity, referred to below as 'ADR cycle'. The artifact is reproduced in Figure 5.

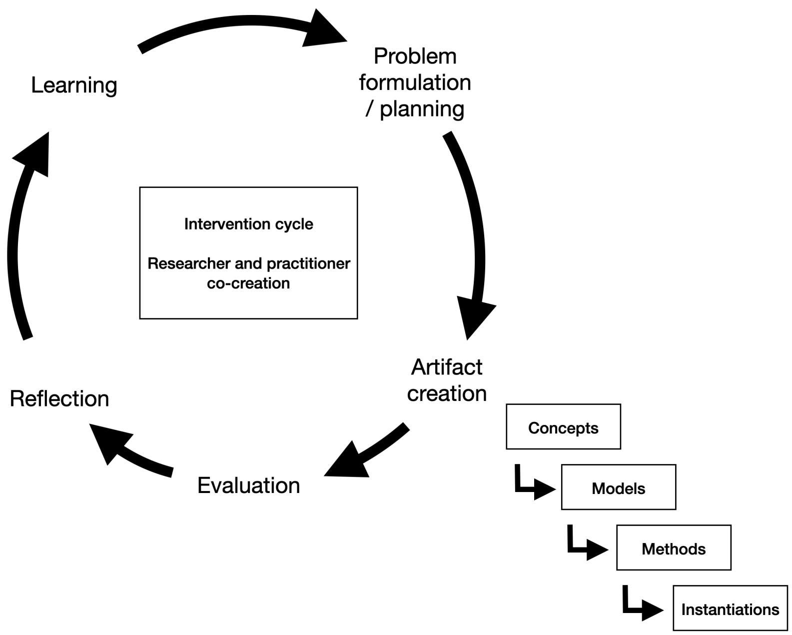


Figure 5. Mullarkey and Hevner's (2019) elaborated action design research cycle

Relationships between artifact, object and interpretation: The purpose of the ADR cycle (the visual artifact) is to convey structural understanding of ADR interventions. The represented process structure has several attributes. It distinguishes five research activities: problem formulation/planning, artifact creation, evaluation, reflection, and learning, which can be repeated in cycles. As the artifact creation activity can be repeated in cycles, it generates a variety of IS artifacts: concepts, models, methods, and instantiations. The ADR cycle also links the research activities to a set of design principles that frame the ADR process.

Intentionality: From the outset, it may be tempting to immediately infer that the artifact's role of the ADR cycle is designing. However, a more careful consideration of the authors' intentionality leads towards a different conclusion. In fact, the authors are broadly focused on research, detailing the various research activities and highlighting their cyclic occurrences. That is, the focus in on the ADR process; the ADR cycle just helps us understand the ADR process. This leads to a classification of the artifact's role as organizing: the main purpose of the ADR cycle is to organize the ADR process. Regarding the research context, the ADR cycle supports the logical link between the original ADR approach and the new proposition. Therefore, it supports sensemaking, showing how the original approach can be further elaborated and complemented towards a more flexible understanding of how researchers and practitioners perform ADR.

Form-and-function: The ADR cycle follows a linear pattern, which interconnects the research activities involved in an ADR process. The form highlights the cyclic execution of ADR processes.

One aspect that may be equivocal is how artifacts emerge from artifact creation. In the textual description, the authors note that "[t]he exact nature of the artifact created will depend upon the stage of the ADR process in which the researcher-practitioner team is currently engaged. There are many types and forms of artifacts that can be created in any ADR cycle or anywhere along the ADR process continuum" (Mullarkey & Hevner, 2019, p. 4). This explanation indicates that contextual factors may determine which artifacts are generated by the ADR cycle. However, the form of the ADR cycle does not reflect such variability, as it only shows linear relationships between artifacts, from concepts to instantiations. This may contribute towards establishing an equivocal understanding of the ADR process.

The effect of the ADR cycle is dimensional, as it categorizes and organizes the research process using the temporal dimension. This effect is well-aligned with what is represented.

Visual scheme: The ADR cycle adopts a sketched scheme, as the visual tokens used to convey meaning incorporate ambiguity in interpretation. For instance, the meaning of the arrows linking artifacts (from concepts to models, methods and instantiations) is unclear, unless the reader analyses the textual description.

Overall, these two examples demonstrate how our framework helps deconstruct a visual artifact. This is done in several analytic stages. The first stage consists of identifying what is represented, what is the intended representation, and what is the role of the artifact in relating the representation with the represented. After a clear understanding of these critical relationships, then the analytic process consecutively addresses intentionality, form-and-function, and visual scheme. As a result, the examples provide evidence that the framework can be applied to analyze key elements of design science visual artifacts.

To some extent, the framework helps to establish a shared understanding among researchers and readers regarding the use of visual artifacts. In particular, the framework can help researchers structure what they intend to say by considering the artifacts' intentionality, form-and-function, and visual scheme, which reduces potential misinterpretations perceived by the readers. It helps develop a narrative structure (from intentionality to realm to scheme), that supports communication between the researcher and the readers. Further, it benefits research teams where multiple researchers use the framework to analyse and discuss their artifacts. By adopting this framework, researchers can focus on how to better design their own research, and how to improve communication using visual artifacts. Conversely, the research community may attach more clear foci and meanings for the use of visual artifacts in design science.

With our framework, we bring visual artifacts to the foreground of design science research. Of course, the design science community can still use artifacts developed in other domains, if necessary. However, our main contribution is highlighting another area where the design science community may further develop its distinctiveness.

In the next section, we discuss in more detail the contributions brought by the framework to the analysis, construction and use of design science visual artifacts.

7 Contributions of the Framework to Design Science

Many design science publications use a variety of visual artifacts to communicate aspects of their research, however, the visual artifacts themselves often stay in the background and are regarded as passive tools. In this research, we reveal how visual artifacts have been helping design science researchers accomplishing a diversity of intentionalities. Besides intentionality, we also highlight how the understanding of form-and-function and visual scheme help researchers achieve intended goals. The articulation between intentionality, form-and-function and visual scheme provides a coherent narrative structure, which supports our understanding of the nature and purpose of visual artifacts. This narrative structure also helps researchers understand what properties should be focused on when developing their visual artifacts. We argue these contributions can be usefully discussed by assessing three properties: transparency, self-sufficiency and consistency.

Transparency (of the relationship between representation and object). In this study, we highlight how visual artifacts are instrumental when communicating about design science. We find that the transparency property helps characterize the communication of design science as a process that transfers knowledge from the researcher to the reader without distortion (Vom Brocke et al., 2021). In helping to accomplish this goal, we highlight that the relationships between visual artifact, object and interpretation must be carefully crafted, as we require visual artifacts to be transparent, otherwise misguided or unclear representations and interpretations may be generated.

Considering that visual artifacts take such an important role in delivering transparency, our study proposes a typology of intentionalities taken by researchers when building a visual artifact. The consideration of intentionality addresses four research roles (we do not exclude combinations): organizing, mapping, scaffolding, and designing. These roles cover a wide range of concerns. Some roles are not specific to design science, such as organizing and mapping. However, designing and scaffolding are unique to design science. The consideration of intentionality also involves two research contexts: sensemaking, where the focus is to make sense of the research; and conceptual output, where the focus is on communicating the final insights of the research. We suggest that this typology of intentionality helps make the construction and use of visual artifacts more transparent, as they can more clearly relate the object and the representation.

As we demonstrate using examples, a more detailed classification of visual artifacts according to form-and-function and visual scheme also contributes to transparency. This may happen through the analysis of cognitive dissonances, potential misinterpretations, ambiguities, and even misalignments, between artifact, object and interpretation. The framework also highlights a range of elements that can be used to identify these issues, focusing on form, function, and visual scheme.

One aspect that emerges from this study is that design science visual artifacts are diverse, because the research they seek to represent is also diverse. This is reminiscent of the law of requisite variety, from cybernetics, where the variety (or distinctiveness) in regulating a system should be on par with the variety found in the regulated system (Ashby & Goldstein, 2011). Our framework recognizes variety in design science and suggests an approach that concurrently recognizes and structures the variety of design science representations and interpretations.

Self-sufficiency (of the visual artifact). Along with the pursuit of a better understanding of the nature and purpose of visual artifacts, we also contribute to the development of more self-sufficient artifacts. The self-sufficiency property refers to a condition where something is independent and can stand by itself, providing effective means for future researchers to build on existing cases (Avdiji et al., 2020). Ideally, design science visual artifacts would be self-sufficient, fully explaining the structure of what is represented—and being independent from the accompanying narrative. By promoting the creation and use of self-sufficient visual artifacts, we contribute to design science by increasing the opportunities for subsequent uses by research and practice. Shepherd and Suddaby (2017) highlight that important research involves "good stories". Visual objects can contribute to create and communicate such "good stories". Bietti et al. (2018) note that stories bring benefits to practitioners and organizations. Therefore, we regard self-sufficient visual artifacts as important tools for disseminating design science to practitioners and organizations.

As we have demonstrated using examples, when doubts arise regarding what the visual artifact is intended to represent, the textual description often provides a more reliable, if not essential, medium to access meaning. This situation makes the visual artifact a useful visual summary of the textual narrative, but an accessory resource in advancing research. Our framework, by promoting a generic conceptual structure for visual artifacts organized in terms of intentionality, form-and-function, and visual scheme, contributes to self-sufficiency. Of course, we do not suggest that these three elements are necessary and sufficient for a generic and complete characterization of design science visual artifacts; but we nevertheless argue they fundamentally contribute towards that goal. Intentionality is critical to understand what the artifact is trying to represent, and form-and-function and visual scheme are essential holistic components for its interpretation.

Even though we provide a contribution towards self-sufficiency, we nevertheless recognize some important limitations requiring further research. In particular, we recall that, often, intentionality is not expressed in the artifact itself, but rather it is expressed by the researcher in other ways. Finding ways to explicitly incorporate intentionality in the artifact would increase self-sufficiency.

We also realize that design science is often supported by combinations of visual artifacts. For example, Sturm and Sunyaev (2019) relate two interesting artifacts in their research: a map that links an IS artifact with meta-requirements and design principles; and an abstract architecture of IS artifacts, which links design components to design principles. This example suggests that design science often involves the combination of visual artifacts, each addressing a particular context and role in a study. Therefore, the concept of self-sufficiency needs to be further investigated, taking into consideration how to combine visual artifacts, and what concerns are essential to make sense of such combinations. We recognize that our research only provides a step in that direction, as the relationships between multiple artifacts have not been analyzed.

Consistency (of communication). Design science is recognized not only as a way to conduct research that generates innovative solutions, but also as a way to generalize solutions and apply them in other interventions. As such, we regard the development of a common design science language as important in communicating about design science in both research and practice.

Therefore, another contribution of this study is that, by establishing a consistent language around design science visual artifacts, which addresses aspects of intentionality, form-and-function, and visual scheme, we contribute to communicating about design science more consistently. We do not suggest a standardization of the research process, the knowledge creation process, the design outputs, the design process, or even the thinking process. We instead provide a narrative structure and a set of properties for consistent use of visual artifacts in design science.

8 Concluding Remarks

The main contribution of this study is to bring a cognitive viewpoint over design science visual artifacts to the foreground of design science. It seems undeniable that visual artifacts have an important role in design science. A timely remark by Simon (1996) states that representation is inherent to the design of the artificial. However, visual artifacts often take secondary roles in design science: they help create representations; but at the same time, they subside under the relevance of what is represented. However, as we advance our understanding of the nature and uses of design science visual artifacts, we realize their relevance in communicating the different dimensions of design science.

In this study, we propose a framework characterizing the nature and purpose of design science visual artifacts. The main purpose is to help researchers organize and communicate their research through a better use of visual artifacts. Based on semiotics, we consider the relationships between artifact, object and interpretation. Then, based on a cognitive theory of visualization of thought, we regard these relationships in three different domains: intentionality, which concerns what the researcher is trying to achieve with the artifact; form-and-function, which establishes the relationships between artifact and object; and visual scheme, which concerns how the artifact is interpreted, using visual tokens.

Besides semiotics and visualization of thought, our framework is also informed by a review of visual artifacts published in the design science literature. Based on the review, we typify and characterize, in detail, the intentionality, form-and-function, and visual scheme adopted by the artifacts in the dataset. We also identify a set of characteristics inherent to these artifacts: 1) diversity of intentionalities and approaches; 2) lightweight conceptualizations; and 3) notational visual schemes with isolated items and groups related through influences. The result is a detailed framework, which identifies many elements that structure the analysis, construction and use of visual artifacts.

We then use two examples from the design science literature to exemplify how the framework can be used to analyze visual artifacts according to intentionality, form-and-function, and visual scheme. Finally, we discuss three specific contributions our framework brings to design science: increasing transparency in the relationships between the representations and what is represented; increasing the self-sufficiency of visual artifacts; and bringing consistency to the communication of design science through visual artifacts.

This study provides implication for both research and practice. From a research perspective, we suggest that to create and use a design science visual artifact, researchers should start by considering intentionality, then should consider form-and-function, and finally should consider the visual scheme. Intentionality categorizes a visual artifact in two dimensions: research context, and research roles. In relation to research context, we consider sensemaking (about specific aspects of the research) and conceptual output (final insights from the research). Regarding research roles, we consider four categories: organizing, mapping, scaffolding, and designing. The consideration for form-and-function allows the researcher to define the structure of the relationships between artifact and design science. Finally, the consideration for a visual scheme allows the researcher to define the overall schematization of the artifact, and how concept and relationship tokens contribute to enact the intended interpretations.

From a practical perspective, this study helps bridge the gap between academics and practitioners. Here, we consider four points. First, our framework can be used as a tool for IS practitioners to engage with design science visual artifacts contributed by the research community. Aspects such as intentionality and form-and-function, if adequately communicated, can be instrumental for appropriating, contextualizing and applying the outputs of design science studies in specific applications. Second, we further suggest self-sufficiency as a key property of a visual artifact. With the self-sufficiency property, we expect that a design science visual artefact can stand by itself and provide reuse potential, if not iconic value, for IS practitioners. Furthermore, our review suggests that, even though design science visual artifacts are predominantly notational, they do not require prior knowledge of complicated notations and standards. Third, this study promotes the usage of visual artifacts in problem solving. As design science mainly addresses practical problems from application domains (Hevner et al., 2004), we expect that transparent, self-sufficient and consistent visual artifacts will play more important roles in representing and articulating practical problems and their solutions. Finally, many design science studies involve organizational interventions and are expected to deliver value to organizations. In this regard, visual artifacts, functioning as mediators between researchers and organizations, can improve communication.

Finally, we also recognize that our framework is essentially a set of exploratory propositions, which should be open to further inquiry. Even though we contribute towards establishing a consistent language around design science visual artifacts, we do not develop a visual schema. Future research could focus on developing a visual schema for design science visual artifacts that would promote transparency, self-sufficiency and consistency. Such development would be comparable to efforts made in other fields, such as software engineering (e.g., Unified Modelling Language) and process management (e.g., Business Process Management Notation), but with a specific set of requirements for design science.

9 References

Abbasi, A., Albrecht, C., Vance, A., & Hansen, J. (2012). Metafraud: A Meta-Learning Framework for Detecting Financial Fraud. *MIS Quarterly*, *36*(4), 1293-A12. https://doi.org/10.2307/41703508

Abbasi, A., & Chen, H. (2008). CyberGate: A design framework and system for text analysis of computer-mediated communication. *MIS Quarterly*, *32*(4), 811–837.

Abbasi, A., Li, J., Adjeroh, D., Abate, M., & Zheng, W. (2019). Don't Mention It? Analyzing User-Generated Content Signals for Early Adverse Event Warnings. *Information Systems Research*, *30*(3), 1007–1028. https://doi.org/10.1287/isre.2019.0847

Abbasi, A., Zhou, Y., Deng, S., & Zhang, P. (2018). Text Analytics to Support Sense-Making in Social Media: A Language-Action Perspective. *MIS Quarterly*, *42*(2), 427-A38.

Albert, T., Goes, P., & Gupta, A. (2004). Gist: A Model for Design and Management of Content and Interactivity of Customer-Centric Web Sites. *MIS Quarterly*, *28*(2), 161–182. https://doi.org/10.2307/25148632

Allen, G., & March, S. (2012). A research note on representing part-whole relations in conceptual modeling. *MIS Quarterly*, 945–964.

Alter, S. (2015). The concept of 'IT artifact' has outlived its usefulness and should be retired now. *Information Systems Journal*, *25*(1), 47–60.

Arnott, D. (2006). Cognitive biases and decision support systems development: A design science approach. *Information Systems Journal*, *16*(1), 55–78. https://doi.org/10.1111/j.1365-2575.2006.00208.x

Ashby, W., & Goldstein, J. (2011). Variety, constraint, and the law of requisite variety. *Emergence: Complexity and Organization*, *13*(1/2), 190.

Astor, P., Adam, M., Jerčić, P., Schaaff, K., & Weinhardt, C. (2013). Integrating Biosignals into Information Systems: A NeuroIS Tool for Improving Emotion Regulation. *Journal of Management Information Systems*, *30*(3), 247–278. https://doi.org/10.2753/MIS0742-1222300309

Avdiji, H., Elikan, D., Missonier, S., & Pigneur, Y. (2020). A design theory for visual inquiry tools. *Journal of the Association for Information Systems*, *21*(3), 3.

Baskerville, R., Baiyere, A., Gregor, S., Hevner, A., & Rossi, M. (2018). Design Science Research Contributions: Finding a Balance between Artifact and Theory. *Journal of the Association for Information Systems*, *19*(5), 358–376.

Baskerville, R., Kaul, M., & Storey, V. (2011). Unpacking the duality of design science. *Thirty Second International Conference on Information Systems*.

Baskerville, R., Kaul, M., & Storey, V. (2015). Genres of inquiry in design-science research: Justification and evaluation of knowledge production. *MIS Quarterly*, *39*(3), 541–564.

Baskerville, R., Kaul, M., & Storey, V. (2018). Aesthetics in design science research. *European Journal of Information Systems*, *27*(2), 140–153.

Baskerville, R., & Myers, M. (2015). Design ethnography in information systems. *Information Systems Journal*, *25*(1), 23–46. https://doi.org/10.1111/isj.12055

Baskerville, R., & Vaishnavi, V. (2016). Pre-theory design frameworks and design theorizing. *49th Hawaii International Conference on System Sciences*, 4464–4473.

Becker, J., Beverungen, D., Knackstedt, R., Rauer, H., & Sigge, D. (2014). On the ontological expressiveness of conceptual modeling grammars for service productivity management. *Information Systems and E-Business Management*, *12*(3), 337–365.

Bera, P., Burton-Jones, A., & Wand, Y. (2014). Research note—How semantics and pragmatics interact in understanding conceptual models. *Information Systems Research*, *25*(2), 401–419.

Beynon-Davies, P. (2018). What's in a face? Making sense of tangible information systems in terms of Peircean semiotics. *European Journal of Information Systems*, *27*(3), 295–314.

Bietti, L., Tilston, O., & Bangerter, A. (2018). Storytelling as adaptive collective sensemaking. *Topics in Cognitive Science*, 1–23.

Blackwell, A., Britton, C., Cox, A., Green, T., Gurr, C., Kadoda, G., Kutar, M., Loomes, M., Nehaniv, C., & Petre, M. (2001). Cognitive dimensions of notations: Design tools for cognitive technology. In *International Conference on Cognitive Technology* (pp. 325–341). Springer.

Blackwell, A., Church, L., Plimmer, B., & Gray, D. (2008). Formality in sketches and visual representation: Some informal reflections. *Creativity Research Journal*, 11–18.

Blackwell, A., & Richards, C. (2019). A pattern language for the design of diagrams. In *Elements of Diagramming: Design, Theories, Analyses and Methods*. Taylor and Francis.

Boxenbaum, E., Jones, C., Meyer, R., & Svejenova, S. (2018). Towards an articulation of the material and visual turn in organization studies. *Organization Studies39*, *5–6*(5–6), 597–616.
Brandt, T., Feuerriegel, S., & Neumann, D. (2018). Modeling interferences in information systems design for cyber-physical systems: Insights from a smart grid application. *European Journal of Information Systems*, *27*(2), 207–220. https://doi.org/10.1057/s41303-016-0030-1
Brödner, P. (2019). Coping with Descartes' error in information systems. *AI & SOCIETY*, *34*(2), 203–213.
Burton-Jones, A., Recker, J., Indulska, M., Green, P., & Weber, R. (2017). Assessing representation theory with a framework for pursuing success and failure. *MIS Quarterly*, *41*(4), 1307–1333.
Cascavilla, G., Conti, M., Schwartz, D., & Yahav, I. (2018). The insider on the outside: A novel system for the detection of information leakers in social networks. *European Journal of Information Systems*, *27*(4), 470–485. https://doi.org/10.1080/0960085X.2017.1387712
Chanson, M., Bogner, A., Bilgeri, D., Fleisch, E., & Wortmann, F. (2019). Blockchain for the IoT: privacy-preserving protection of sensor data. *Journal of the Association for Information Systems*, *20*(9), 1274–1309.
Chatterjee, S., Byun, J., Dutta, K., Pedersen, R., Pottathil, A., & Xie, H. (2018). Designing an Internet-of-Things (IoT) and sensor-based in-home monitoring system for assisting diabetes patients: Iterative learning from two case studies. *European Journal of Information Systems*, *27*(6), 670–685. https://doi.org/10.1080/0960085X.2018.1485619
Chaturvedi, A., Dolk, D., & Drnevich, P. (2011). Design Principles for Virtual Worlds. *MIS Quarterly*, *35*(3), 673–684. https://doi.org/10.2307/23042803
Chau, M., & Xu, J. (2012). Business Intelligence in Blogs: Understanding Consumer Interactions and Communities. *MIS Quarterly*, *36*(4), 1189–1216. https://doi.org/10.2307/41703504
Chen, R., Sharman, R., Rao, H., & Upadhyaya, S. (2013). Data Model Development for Fire Related Extreme Events: An Activity Theory Approach1. *MIS Quarterly*, *37*(1), 125–147.
Cheng, X., Fu, S., & Druckenmiller, D. (2016). Trust Development in Globally Distributed Collaboration: A Case of U.S. and Chinese Mixed Teams. *Journal of Management Information Systems*, *33*(4), 978–1007. https://doi.org/10.1080/07421222.2016.1267521
Choi, J., Nazareth, D., & Jain, H. (2010). Implementing Service-Oriented Architecture in Organizations. *Journal of Management Information Systems*, *26*(4), 253–286. https://doi.org/10.2753/MIS0742-1222260409
Coenen, T., Coertjens, L., Vlerick, P., Lesterhuis, M., Mortier, A. V., Donche, V., Ballon, P., & Maeyer, S. (2018). An information system design theory for the comparative judgement of competences. *European Journal of Information Systems*, *27*(2), 248–261. https://doi.org/10.1080/0960085X.2018.1445461
Currim, F., & Ram, S. (2012). Modeling Spatial and Temporal Set-Based Constraints During Conceptual Database Design. *Information Systems Research*, *23*(1), 109–128. https://doi.org/10.1287/isre.1100.0306
D'Aubeterre, F., Singh, R., & Iyer, L. (2008). A Semantic Approach to Secure Collaborative Inter- Organizational eBusiness Processes (SSCIOBP). *Journal of the Association for Information Systems*, *9*(3), 231–266.
Evermann, J. (2005). Towards a cognitive foundation for knowledge representation. *Information Systems Journal*, *15*(2), 147–178.
Fahmideh, M., Daneshgar, F., Rabhi, F., & Beydoun, G. (2019). A generic cloud migration process model. *European Journal of Information Systems*, *28*(3), 233–255.
Friedman, A., & Thellefsen, M. (2011). Concept theory and semiotics in knowledge organization. *Journal of Documentation*.
Galle, P. (2008). Candidate worldviews for design theory. *Design Studies*, *29*(3), 267–303.
Ghajargar, M., & Wiberg, M. (2018). Thinking with interactive artifacts: Reflection as a concept in design outcomes. *Design Issues*, *34*(2), 48–63.
Goel, V. (1995). *Sketches of Thought*. The MIT Press.
Goel, V., & Pirolli, P. (1992). The structure of design problem spaces. *Cognitive Science*, *16*(3), 395–429.
Goldkuhl, G. (2013). From ensemble view to ensemble artefact–An inquiry on conceptualisations of the IT artefact. *Systems, Signs & Actions*, *7*(1), 49–72.
Green, T. (1989). Cognitive dimensions of notations. *People and Computers V*, 443–460.
Gregor, S., & Hevner, A. (2011). Introduction to the special issue on design science. *Information Systems and E-Business Management*, *9*(1), 1–9.
Gregor, S., & Hevner, A. (2013). Positioning and presenting design science research for maximum impact. *MIS Quarterly*, *37*(2), 337–356.

Gregor, S., Imran, A., & Turner, T. (2014). A ‘sweet spot’ change strategy for a least developed country: Leveraging e-Government in Bangladesh. *European Journal of Information Systems*, *23*(6), 655–671.
Gregor, S., & Jones, D. (2007). The Anatomy of a Design Theory. *Journal of the Association of Information Systems*, *8*(5), 312–335.
Grover, V., & Lyytinen, K. (2015). New state of play in information systems research. *MIS Quarterly*, *39*(2), 271–296.
Guo, X., Wei, Q., Chen, G., Zhang, J., & Qiao, D. (2017). Extracting Representative Information on Intra-Organizational Blogging Platforms. *MIS Quarterly*, *41*(4), 1105-5-A12.
Hevner, A., March, S., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, *28*(1), 75–105.
Huber, R., Püschel, L. C., & Röglinger, M. (2019). Capturing smart service systems: Development of a domain-specific modelling language. *Information Systems Journal*, *29*(6), 1207–1255. https://doi.org/10.1111/isj.12269
Iivari, J. (2017). Information system artefact or information system application: That is the question. *Information Systems Journal*, *27*(6), 753–774. https://doi.org/10.1111/isj.12121
Iivari, J. (2020). A Critical Look at Theories in Design Science Research. *Journal of the Association for Information Systems*, *21*(3), 502–519.
Ji Wu, Liqiang Huang, & Zhao, J. L. (2019). Operationalizing Regulatory Focus in the Digital Age: Evidence from an E-Commerce Context. *MIS Quarterly*, *43*(3), 745-A16. https://doi.org/10.25300/MISQ/2019/14420
John, B., Chua, A., Goh, D., & Wickramasinghe, N. (2016). Graph-based Cluster Analysis to Identify Similar Questions: A Design Science Approach. *Journal of the Association for Information Systems*, *17*(9), 590–613.
Keith, M., Demirkan, H., & Goul, M. (2013). Service-Oriented Methodology for Systems Development. *Journal of Management Information Systems*, *30*(1), 227–260. https://doi.org/10.2753/MIS0742-1222300107
Ketter, W., Peters, M., Collins, J., & Gupta, A. (2016a). A Multiagent Competitive Gaming Platform to Address Societal Challenges. *MIS Quarterly*, *40*(2), 447–460.
Ketter, W., Peters, M., Collins, J., & Gupta, A. (2016b). Competitive Benchmarking: An Is Research Approach to Address Wicked Problems with Big Data and Analytics. *MIS Quarterly*, *40*(4), 1057–1089.
Klein, G., Moon, B., & Hoffman, R. (2006). Making sense of sensemaking 2: A macrocognitive model. *IEEE Intelligent Systems*, *21*(5), 88–92.
Klier, J., Klier, M., Thiel, L., & Agarwal, R. (2019). Power of Mobile Peer Groups: A Design-Oriented Approach to Address Youth Unemployment. *Journal of Management Information Systems*, *36*(1), 158–193. https://doi.org/10.1080/07421222.2018.1550557
Kloör, B., Monhof, M., Beverungen, D., & Braäer, S. (2018). Design and evaluation of a model-driven decision support system for repurposing electric vehicle batteries. *European Journal of Information Systems*, *27*(2), 171–188. https://doi.org/10.1057/s41303-017-0044-3
Kolfschoten, G., & Vreede, G. (2009). A Design Approach for Collaboration Processes: A Multimethod Design Science Study in Collaboration Engineering. *Journal of Management Information Systems*, *26*(1), 225–256. https://doi.org/10.2753/MIS0742-1222260109
Kolkowska, E., Karlsson, F., & Hedström, K. (2017). Towards analysing the rationale of information security non-compliance: Devising a Value-Based Compliance analysis method. *The Journal of Strategic Information Systems*, *26*(1), 39–57. https://doi.org/10.1016/j.jsis.2016.08.005
Kuechler, B., & Vaishnavi, V. (2008). On theory development in design science research: Anatomy of a research project. *European Journal of Information Systems*, *17*(5), 489–504.
Kuechler, W., & Vaishnavi, V. (2012). A framework for theory development in design science research: Multiple perspectives. *Journal of the Association for Information Systems*, *13*(6), 395–423.
Langley, A., & Ravasi, D. (2019). Visual artifacts as tools for analysis and theorizing. In *The production of managerial knowledge and organizational theory: New approaches to writing, producing and consuming theory* (Vol. 59). Emerald Publishing Limited.
Lee, J. (2016). Reflections on ICT-enabled Bright Society Research. *Information Systems Research*, *27*(1), 1–5. https://doi.org/10.1287/isre.2016.0627
Lycett, M., & Radwan, O. (2019). Developing a Quality of Experience (QoE) model for Web Applications. *Information Systems Journal*, *29*(1), 175–199. https://doi.org/10.1111/isj.12192
March, S., & Smith, G. (1995). Design and natural science research on information technology. *Decision Support Systems*, *15*(4), 251–266.

Mastrogiacomo, S., Missonier, S., & Bonazzi, R. (2014). Talk Before It's Too Late: Reconsidering the Role of Conversation in Information Systems Project Management. *Journal of Management Information Systems*, *31*(1), 47–78. https://doi.org/10.2753/MIS0742-1222310103

McKinney Jr, E., & Yoos, C. (2010). Information about information: A taxonomy of views. *MIS Quarterly*, 329–344.

Meredith, J. (1993). Theory Building through Conceptual Methods. *International Journal of Operations & Production Management*, *13*(5), 3–11.

Meth, H., Mueller, B., & Maedche, A. (2015). Designing a Requirement Mining System. *Journal of the Association for Information Systems*, *16*(9), 799–837.

Miles, M., Huberman, A., & Saldaña, J. (2014). *Qualitative Data Analysis: A Methods Sourcebook*. Sage Publications.

Mingers, J., & Willcocks, L. (2014). An integrative semiotic framework for information systems: The social, personal and material worlds. *Information and Organization*, *24*(1), 48–70.

Mingers, J., & Willcocks, L. (2017). An integrative semiotic methodology for IS research. *Information and Organization*, *27*(1), 17–36.

Mullarkey, M., & Hevner, A. (2019). An elaborated action design research process model. *European Journal of Information Systems*, *28*(1), 6–20.

Närman, P., Holm, H., Ekstedt, M., & Honeth, N. (2013). Using enterprise architecture analysis and interview data to estimate service response time. *The Journal of Strategic Information Systems*, *22*(1), 70–85. https://doi.org/10.1016/j.jsis.2012.10.002

Nickerson, J., Corter, J., Tversky, B., Rho, Y.-J., Zahner, D., & Yu, L. (2013). Cognitive tools shape thought: Diagrams in design. *Cognitive Processing*, *14*(3), 255–272.

Niederman, F., & March, S. (2019). The "Theoretical Lens" Concept: We All Know What it Means, but do We All Know the Same Thing? *Communications of the Association for Information Systems*, *44*(1), 1.

Niehaves, B., & Ortbach, K. (2016). The inner and the outer model in explanatory design theory: The case of designing electronic feedback systems. *European Journal of Information Systems*, *25*(4), 303–316. Scopus. https://doi.org/10.1057/ejis.2016.3

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. Oxford university press.

Nunamaker, J., Chen, M., & Purdin, T. (1990). Systems development in information systems research. *Journal of Management Information Systems*, *7*(3), 89–106.

Oetzel, M., & Spiekermann, S. (2014). A systematic methodology for privacy impact assessments: A design science approach. *European Journal of Information Systems*, *23*(2), 126–150. https://doi.org/10.1057/ejis.2013.18

Paré, G., Tate, M., Johnstone, D., & Kitsiou, S. (2016). Contextualizing the twin concepts of systematicity and transparency in information systems literature reviews. *European Journal of Information Systems*, *25*(6), 493–508.

Paré, G., Trudel, M., Jaana, M., & Kitsiou, S. (2015). Synthesizing information systems knowledge: A typology of literature reviews. *Information & Management*, *52*(2), 183–199.

Parsons, J., & Ralph, P. (2014). Generating Effective Recommendations Using Viewing-Time Weighted Preferences for Attributes. *Journal of the Association for Information Systems*, *15*(8), 484–513.

Peffers, K., Tuunanen, T., Rothenberger, M., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems*, *24*(3), 45–77.

Piccoli, G., Rodriguez, J., Palese, B., & Bartosiak, M. (2019). Feedback at scale: Designing for accurate and timely practical digital skills evaluation. *European Journal of Information Systems*, *0*(0), 1–20. https://doi.org/10.1080/0960085X.2019.1701955

Piel, J., Hamann, J., Koukal, A., & Breitner, M. (2017). Promoting the System Integration of Renewable Energies: Toward a Decision Support System for Incentivizing Spatially Diversified Deployment. *Journal of Management Information Systems*, *34*(4), 994–1022. https://doi.org/10.1080/07421222.2017.1394044

Popper, K. (1979). *Three Worlds, The Tanner Lecture on Human Values*.

Pries-Heje, J., & Baskerville, R. (2008). The design theory nexus. *MIS Quarterly*, *32*(4), 731–755.

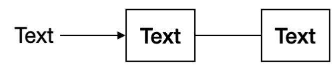
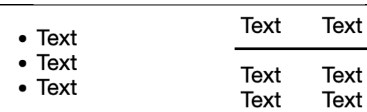
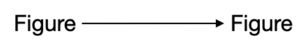
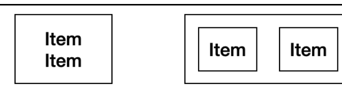
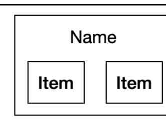
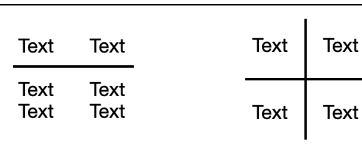
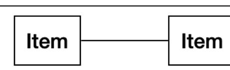
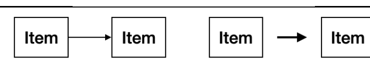
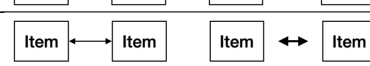
Ravasi, D. (2017). Visualizing our way through theory building. *Journal of Management Inquiry*, *26*(2), 240–243.

Recker, J., Indulska, M., Green, P., Burton-Jones, A., & Weber, R. (2019). Information Systems as Representations: A Review of the Theory and Evidence. *Journal of the Association for Information Systems*, *20*(6), 5.

Reinecke, K., & Bernstein, A. (2013). Knowing What a User Likes: A Design Science Approach to Interfaces That Automatically Adapt to Culture. *MIS Quarterly*, *37*(2), 427-A11.
Roussinov, D., & Chau, M. (2008). Combining Information Seeking Services into a Meta Supply Chain of Facts. *Journal of the Association for Information Systems*, *9*(3), 175–199.
Schmeil, A., Eppler, M., & de Freitas, S. (2012). A Structured Approach for Designing Collaboration Experiences for Virtual Worlds. *Journal of the Association for Information Systems*, *13*(10), 836–860.
Schön, D. (1983). *The reflective practitioner: How professionals think in action*. Basic Books.
Schön, D., & Wiggins, G. (1992). Kinds of seeing and their functions in designing. *Design Studies*, *13*(2), 135–156.
Seidel, S., Kruse, L. C., Székely, N., Gau, M., & Stieger, D. (2018). Design principles for sensemaking support systems in environmental sustainability transformations. *European Journal of Information Systems*, *27*(2), 221–247. https://doi.org/10.1057/s41303-017-0039-0
Sein, M., Henfridsson, O., Purao, S., Rossi, M., & Lindgren, R. (2011). Action design research. *MIS Quarterly*, *35*(1), 37–56.
Shepherd, D., & Suddaby, R. (2017). Theory building: A review and integration. *Journal of Management*, *43*(1), 59–86.
Siegert, B. (2011). The map is the territory. *Radical Philosophy*, *5*, 13–16.
Silic, M., & Lowry, P. (2020). Using Design-Science Based Gamification to Improve Organizational Security Training and Compliance. *Journal of Management Information Systems*, *37*(1), 129–161. https://doi.org/10.1080/07421222.2019.1705512
Simon, H. (1996). *The Sciences of the Artificial* (Third Edition). The MIT Press.
Sturm, B., & Sunyaev, A. (2019). Design principles for systematic search systems: A holistic synthesis of a rigorous multi-cycle design science research journey. *Business & Information Systems Engineering*, *61*(1), 91–111.
Suwa, M., & Tversky, B. (1997). What do architects and students perceive in their design sketches? A protocol analysis. *Design Studies*, *18*(4), 385–403.
Tversky, B. (2014). Visualizing thought. In *Handbook of human centric visualization* (pp. 3–40). Springer.
Umapathy, K., Purao, S., & Barton, R. (2008). Designing enterprise integration solutions: Effectively. *European Journal of Information Systems*, *17*(5), 518–527. https://doi.org/10.1057/ejis.2008.39
VanderMeer, D., Dutta, K., & Datta, A. (2012). A Cost-Based Database Request Distribution Technique for Online E-Commerce Applications. *MIS Quarterly*, *36*(2), 479–507. https://doi.org/10.2307/41703464
Varghese, P. (2019). A Thought on Models of Design Processes: Abstraction, Representation and Reality. In *Research into Design for a Connected World* (pp. 75–85). Springer.
Velichety, S., Ram, S., & Bockstedt, J. (2019). Quality Assessment of Peer-Produced Content in Knowledge Repositories using Development and Coordination Activities. *Journal of Management Information Systems*, *36*(2), 478–512. https://doi.org/10.1080/07421222.2019.1598692
Venable, J., Pries-Heje, J., & Baskerville, R. (2016). FEDS: a framework for evaluation in design science research. *European Journal of Information Systems*, *25*(1), 77–89.
Venkatesh, V., Aloysius, J., Hoehle, H., & Burton, S. (2017). Design and Evaluation of Auto-Id Enabled Shopping Assistance Artifacts in Customers' Mobile Phones: Two Retail Store Laboratory Experiments. *MIS Quarterly*, *41*(1), 83–114.
Vom Brocke, J., Gau, M., & Mädche, A. (2021). Journaling the Design Science Research Process. Transparency About the Making of Design Knowledge. *International Conference on Design Science Research in Information Systems and Technology*, 131–136.
Vom Brocke, J., Winter, R., Hevner, A., & Maedche, A. (2020). Accumulation and Evolution of Design Knowledge in Design Science Research – A Journey Through Time and Space. *Journal of the Association for Information Systems*.
Walls, J., Widmeyer, G., & El Sawy, O. (1992). Building an information system design theory for vigilant EIS. *Information Systems Research*, *3*(1), 36–59.
Wand, Y., & Weber, R. (1990). Toward a theory of the deep structure of information systems. *International Conference on Information Systems*, 3.
Wand, Y., & Weber, R. (2002). Research commentary: Information systems and conceptual modeling—A research agenda. *Information Systems Research*, *13*(4), 363–376.
Weigand, H., Johannesson, P., & Andersson, B. (2021). An artifact ontology for design science research. *Data & Knowledge Engineering*, *133*, 101878.

Williams, K., Chatterjee, S., & Rossi, M. (2008). Design of emerging digital services: A taxonomy. *European Journal of Information Systems*, *17*(5), 505–517. https://doi.org/10.1057/ejis.2008.38
Winter, R. (2008). Design science research in Europe. *European Journal of Information Systems*, *17*(5), 470–475.
Wyssusek, B. (2006). On ontological foundations of conceptual modelling. *Scandinavian Journal of Information Systems*, *18*(1), 9.
Xu, J., Wang, G., Jiexun Li, & Chau, M. (2007). Complex Problem Solving: Identity Matching Based on Social Contextual Information. *Journal of the Association for Information Systems*, *8*(10), 525–545.
Yang, Y., Singhal, S., & Xu, Y. (2012). Alternate Strategies for a Win-Win Seeking Agent in Agent-Human Negotiations. *Journal of Management Information Systems*, *29*(3), 223–256. https://doi.org/10.2753/MIS0742-1222290307
Zachman, J. (1987). A framework for information systems architecture. *IBM Systems Journal*, *26*(3), 276–292.

Appendix A: Examples of Visual Tokens Coded in Relation to Visual Scheme

Schematization	**Main features**	**Illustrative examples**
- Notational	Combination of text and recognizable visual tokens	
- Discursive	Use of natural language in combination with few visual tokens	
- Sketched	Use of non-notational visual tokens	
Concept tokens		
- Items	Singular visual tokens	
- Groups	Collections of items	
- Classes	Groups of visual tokens suggesting composition	
Relationship tokens		
- Implicit	Established by context	
- Associations	Directed or non-directed links between concepts	
- Influences	Directed, cause-effect links	
- Mutual influences	Bi-directional links	

Appendix B: Reviewed Artifacts

Table A. List of artifacts

Nr.	**Reference**	**Page**	**Figure**
1.	(Abbasi et al., 2012)	1303	2

2.	(Abbasi et al., 2019)	1010	1
3.	(Arnott, 2006)	58	1
4.	(Astor et al., 2013)	256	1
5.	(Baskerville & Myers, 2015)	32	1
6.	(Baskerville et al., 2015)	550	1
7.	(Baskerville, Kaul, et al., 2018)	141	Table 1
8.	(Baskerville, Baiyere, et al., 2018)	363	2
9.	(Beynon-Davies, 2018)	307	6
10.	(Brandt et al., 2018)	210	2
11.	(Cheng et al., 2016)	983	1
12.	(Choi et al., 2010)	263	1
13.	(Gregor & Jones, 2007)	321	1
14.	(Gregor et al., 2014)	658	1
15.	(Hevner et al., 2004)	80	2
16.	(Iivari, 2017)	756	1
17.	(B. Kuechler & Vaishnavi, 2008)	492	2
18.	(W. Kuechler & Vaishnavi, 2012)	399	1
19.	(Lee, 2016)	2	2
20.	(Lycett & Radwan, 2019)	178	1
21.	(Oetzel & Spiekermann, 2014)	129	2
22.	(Peffers et al., 2007)	54	1
23.	(Pries-Heje & Baskerville, 2008)	734	2
24.	(Seidel et al., 2018)	226	1
25.	(Umapathy et al., 2008)	522	4
26.	(Venable et al., 2016)	80	2
27.	(Williams et al., 2008)	513	1
28.	(Winter, 2008)	472	2
29.	(Abbasi et al., 2018)	432	2
30.	(Abbasi & Chen, 2008)	816	Table 3
31.	(Albert et al., 2004)	168	2
32.	(Cascavilla et al., 2018)	476	1
33.	(Chanson et al., 2019)	1284	4
34.	(Chatterjee et al., 2018)	674	2
35.	(Chaturvedi et al., 2011)	679	1
36.	(Chau & Xu, 2012)	1193	1
37.	(Chen et al., 2013)	129	3
38.	(Coenen et al., 2018)	251	1
39.	(Currim & Ram, 2012)	112	2
40.	(D'Aubeterre et al., 2008)	242	1
41.	(Fahmideh et al., 2019)	237	2
42.	(Guo et al., 2017)	1109	1
43.	(Huber et al., 2019)	1217	3
44.	(Ji Wu et al., 2019)	749	1
45.	(John et al., 2016)	595	1
46.	(Keith et al., 2013)	236	2
47.	(Ketter et al., 2016a)	450	1
48.	(Ketter et al., 2016b)	1065	2
49.	(Klier et al., 2019)	167	1
50.	(Kloör et al., 2018)	143	1
51.	(Kolfschoten & Vreede, 2009)	230	1

52.	(Kolkowska et al., 2017)	45	2
53.	(Mastrogiacomo et al., 2014)	61	1
54.	(Meth et al., 2015)	803	1
55.	(Närman et al., 2013)	73	1
56.	(Niehaves & Ortbach, 2016)	308	1
57.	(Parsons & Ralph, 2014)	491	2
58.	(Piccoli et al., 2019)	8	2
59.	(Piel et al., 2017)	1002	1
60.	(Reinecke & Bernstein, 2013)	436	2
61.	(Roussinov & Chau, 2008)	176	1
62.	(Schmeil et al., 2012)	846	1
63.	(Silic & Lowry, 2020)	133	1
64.	(VanderMeer et al., 2012)	421	1-2
65.	(Velichety et al., 2019)	483	1
66.	(Venkatesh et al., 2017)	93	1
67.	(Xu et al., 2007)	529	1
68.	(Yang et al., 2012)	234	2

Table B. Assigned codes

Codes	Artifacts
Intentionality – research contexts	
Sensemaking	3-4,7-8,10-11,13-14,16,17,19-21,24,34,38,44-45,50-52,54-55,61,64-66
Conceptual output	1-2,5-6,9,12,15,18,22-23,25-33,35-37,39-43,46-49,53,56-60,62-63,67-68
Intentionality –research roles	
Organizing	3,5,11,14,20,22,24,26,28,30,35,37,44-46,50-52,55,65,67
Mapping	7-8,13,19,27,54,61,64
Scaffolding	
- Theory	9,12,15,17,66
- Theorizing	6,53,56,63
- Kernel theory	21
Designing	
- Product	1,4,16,25,31-33,36,40-43,49,57-60,62,68
- Process	10,23,34
- Both (product and process)	2,18,29,39,47-48
Form-and-function	
Form	
- Linear	1,3,10-11,14,18-19,21-22,24,32,35-37,42,44-46,50-52,55,65,67
- Loosely relational	4,6-8,13,15-16,23,25-30,47-49,53-54,56-58,61-64,66,68
- Tightly relational	2,5,12,17,20,31,33-34,38-41,43,59-60
Function	
- Dimensional	6,26-27,53
- Domain	1,7-8,15-17,28-30,33,35,39,47-48,54,56,59-60,62-63,68
- Influence	2-5,9-14,18-25,31-32,34,36-38,40-46,49-52,55,57-58,61,64-67
Visual scheme	
Schematization	
- Notational	1-2,4-6,8,10-12,14-22,24-26,29,31,33-44,48-49,51-52,54-68
- Discursive	3,7,13,27,30,50,53
- Sketched	9,23,28,32,45-47
Concept tokens	
- Items	1,3,5-6,9-31,33-40,42,44,46-53,55-59,61,63-64,66-68

- Groups	1-2,4-5,7-8,10-11,15,21,29,32-33,35-36,39,42,44-45,48,52,54,56,59,61-63,65-68
- Classes	2,16-18,20,22,41,43,60
Relationship tokens	
- Implicit	6-7,15,27-32,34,46,50,62
- Associations	2,11,17,20,31,33,35-36,38-43,47,53-54,56-61,64,67-68
- Influences	1,3-5,8-12,14-24,26,29,32-37,39,44-45,47-49,51-52,54-56,59,63,65-66
- Mutual influences	8,13,16,25,28,35,42,48