Design Principles in Information Systems Research: Trends in Construction and Formulation

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Abstract

Design knowledge has become increasingly important in information systems research in recent years, with Design Science Research (DSR) as an approach to developing innovative and effective artifacts. Design Principles (DPs) have proven to be a popular tool for contributing to abstract design knowledge. The construction and formulation of DPs has become more professional in recent years, with publications providing guidance. However, the implementation by researchers of these rules needs to be investigated. To address this gap, we conducted a systematic literature review, analyzed the various forms of design knowledge that have emerged, and examined the state of design principle construction and formulation. Our analysis shows that in recent years there has been a significant increase in the number of publications dealing with DP design. Our results shed light on the characteristics and evolution of DPs, as well as their construction and formulation, and provide valuable guidance for future research.

Keywords

Design Principles, Design Knowledge, Design Science Research, Literature Review.

Introduction

Over the last decade, design knowledge has grown increasingly in importance in information systems research (vom Brocke et al. 2020). This is because Design Science Research (DSR) has emerged as an approach in information systems research for developing innovative and effective artifacts (Hevner et al. 2004). As a result of the artifact creation process, different types of design knowledge can emerge (vom Brocke et al. 2020). This knowledge may be either present in generalized and abstract form of knowledge (design theory) or may have been specifically implemented as an instantiated artifact (instantiation) (vom Brocke et al. 2020; Gregor and Hevner 2013). Design theories can take many forms, including technological implementation rules, design guidelines, design principles (DPs), constructs, methods or models (Gregor and Hevner 2013). In this realm, DPs have proven to be a popular instrument for contributing abstract design knowledge, and they have been established numerous times in the recent years by various researchers for a wide range of applications (Chandra Kruse et al. 2022; Gregor et al. 2020). The construction and formulation of design has become increasingly systematic over the years (Gregor et al. 2020; Möller et al. 2020).

However, the established rules for constructing and formulating DPs have only recently been developed and therefore, especially more recent processes for the construction of DPs appear to follow these rules only to a limited extent or not at all, and even in the recent past, there seem to be different ways in which DPs

are created and which additional contributions of further design knowledge arise in the process, such as user stories, meta-requirements (MRs), constructs, design features and others (Gregor et al. 2020; Möller et al. 2020, 2022).

To better understand this growing trend in information systems research, we conducted a systematic literature review, extracting the various forms of design knowledge contributed by the identified literature and analyzing the research projects. Hence, our goal is to provide a comprehensive understanding of the evolution of DP construction processes and forms in information systems research over the past decade, as well as the implications of these trends for the field. By examining the development and current state of DP construction and formulation, our study aims to offer valuable insights into the structural, methodical, and content-related properties of the papers identified during our analysis. Researchers will benefit from these insights by gaining a better understanding of the characteristics and evolution of DPs, which can inform improvements in the formulation and systematic derivation of DPs. The research question (RQ) guiding our investigation is:

***RQ**: What are the key trends and implications of the evolving construction processes and forms of design principles in information systems research over the past decade?*

Overall, the contribution of design knowledge is critical to the advancement of the field of information systems research. By understanding the nature and evolution of DPs, researchers can develop innovative and effective IT artifacts that solve real-world problems. Therefore, we aim to contribute to the growing body of knowledge in the area of DSR and specifically DPs.

Related Work

DSR is a research paradigm that focuses on designing and evaluating artifacts to create innovative and practical solutions to real-world problems (Hevner et al. 2004). In this regard, design can be seen as a search or problem-solving process that uses means to achieve desired ends, while evaluation is the process of assessing whether the means achieve the desired end. The outcome is design knowledge, which includes prescriptions (i.e., including means-end relationships) on how specific design choices can lead to desired ends (Hevner 2021). Design knowledge is a critical factor that underpins the design and development of artifacts (Rothe et al. 2020).

The knowledge generated in DSR can be of different types, including descriptive knowledge and prescriptive knowledge (Hevner 2021). Descriptive knowledge refers to understanding of the problem domain and knowledge of the current state of affairs. It is "composed of observations, classifications, measurements, and the cataloging of these descriptions into accessible forms" (Hevner 2021, p. 2). In other words, it's the sense-making of relationships in different phenomena, which is represented in natural laws or patterns (Hevner 2021). Prescriptive knowledge, on the other hand, refers to the knowledge of how to reach a desired ends (e.g., improve the current state of affairs) by incorporating a specific design (i.e., an artifact or individual feature or function). The evaluation of prescriptive knowledge is important and also a component of design knowledge (referred to as evaluation as design knowledge by vom Brocke et al. (2020)) as it is the knowledge of how to assess the effectiveness and efficiency of the artifacts developed (vom Brocke et al. 2020; Iivari 2020). This process generates knowledge of the effectiveness and efficiency of the prescription and demonstrating the validity of the means-end relationship (i.e., evaluation evidence) (vom Brocke et al. 2020).

DPs are an type of abstract form of design knowledge that can be used to inform and guide the design and development of artifacts (Chandra Kruse et al. 2022; Gregor et al. 2020). DPs can be used to guide the design and development process, ensuring that the artifacts developed are fit appropriate for their intended purpose and meet the needs of the stakeholders (Chandra Kruse et al. 2022). The use application of DPs can also help to ensure that the artifacts developed are in accordance with consistent with the current state of knowledge in the problem domain. Subsequently, the goal of DPs is to provide designers with validated prescriptive knowledge to provide guidance for a knowledge-intensive and creative process of designing complex information systems (Chandra Kruse et al. 2022).

Prior research has developed and established various instructions and guidelines in order for design knowledge to be used in an accessible form. Gregor and Jones, for example, presented their anatomy of a design theory in 2007, which contains prescriptions on how to process, capture, and present (nascent)

design theories. A design theory is "a theory about means-end relations, i.e., a projectable means-end relation proposition" (Brendel and Muntermann 2022, p. 4) and its representation includes aspects such as purpose and scope, possible constructs, principles of form and function (referred to as DPs), testable propositions, justificatory knowledge but also principles of implementation, to name but a few. Likewise, Gregor et al. (2020) establish the anatomy of a DP, which also contains rules to represent DPs as comprehensively as possible. Their anatomy pays attention to human actors (e.g., implementer, user, enactor or theorizer) and different levels of complexity. Further it also emphasizes the various perspectives on causality included in the means-end relationship and the underlying mechanisms.

DPs have established themselves to be as an effective means of representing abstract design knowledge, which has led to resulting in an increasing in the number of DPs being published on various application areas in recent years (Chandra Kruse et al. 2022; Purao et al. 2020). Purao et al. (2020) investigated the origins of DPs, and have shown the different ways to generate DPs and establishing criteria for when DPs can and should be generated (e.g., what theories are available or whether an artifact can be studied). Further, they show which phases involve the development of DPs, such as preliminary DPs that are instantiated in a second step and then evaluated and refined, which they refer to as temporality. Schoormann et al. (2022) report activities and a set of four strategies for the iterative and creative development procedure of DPs. Incorporating deductive and inductive modes of theorizing, the strategies are either theory-driven (i.e., deductive DP development before evaluation) or evidence-based, such as inductive problem-solving in which DPs are often created after an artifact evaluation. Möller et al. (2020) distinguish between a reflective and a supportive approach in the construction of DPs. In the reflective approach, the problem is defined and then an artifact is developed from which DPs are subsequently derived. In the supportive approach, DP development is preceded, for example, from empirically collected user requirements and justificatory knowledge (i.e., kernel theories) (Möller et al. 2020).

During the construction of DPs, different concepts of design knowledges are often combined, both upstream and downstream of the DPs. Antecedents (upstream) of DPs is the knowledge that is acquired to construct the DPs and consequently used to derive the DPs. These are for example user stories from interviews or surveys, kernel theories, justificatory knowledge, and merged MRs. Specifications of DPs (downstream) are design features and instantiations (instantiated artifacts). MRs are often developed from justificatory knowledge and/or empirically captured user requirements. These MRs summarize all requirements for an artifact to be designed and are then synthesized into DPs. The requirements of users for an artifact to be designed are often captured empirically, e.g., through interviews or methods of requirements elicitation. These requirements are often formulated and summarized as so-called user stories that capture the design demands of users. Möller et al. (2020) propose a so-called mapping diagram for a clear representation of the synthesis of this preceding work (empirically captured user stories, justificatory knowledge as kernel theories) into MRs and then into DPs, which represents this synthesis in a comprehensible way. Figure 1 shows an exemplary structure for such a mapping diagram. Since DPs are abstract design knowledge that can be instantiated in different ways, some researchers propose so-called design features that show possible concrete and tangible implementations of individual DPs (Meth et al. 2015; Möller et al. 2020). In the case of software artifacts, for example, these can be specific functions or features that concretize the DPs and show an exemplary implementation.

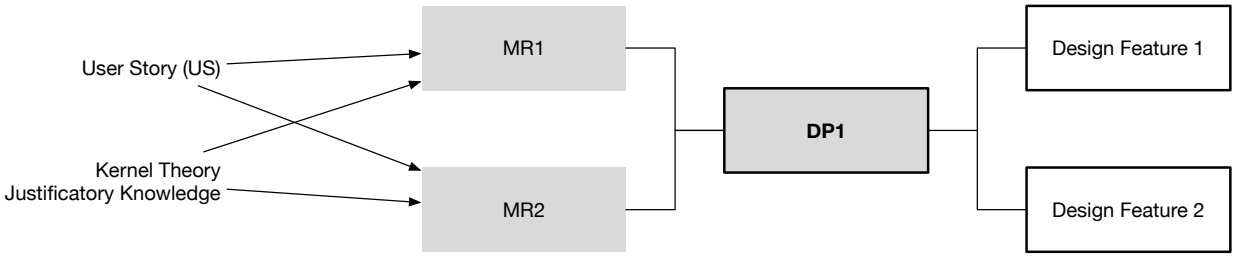

Figure 1. Exemplary Mapping Diagram

In addition, Ivari et al. (2021) dealt with the evaluation and in particular the benefit for practitioners in their establishment of a framework for the minimum reusability evaluation of DPs. The authors affirm that an evaluation of DPs should be concerned with five criteria, namely accessibility, importance, novelty and insightfulness, actability and guidance, and effectiveness. This is especially relevant for practitioners, but also for researchers who want to use, evaluate, and possibly further develop DPs.

A systematic preparation and presentation of DPs according to a stringent anatomy is therefore highly relevant for the accessibility and the associated use (Chandra Kruse et al. 2022; Iivari et al. 2021), evaluation and further development of DPs.

Methodology

To contribute to future research, we performed a systematic literature review based on Webster and Watson (2002), Page et al. (2021) and Schoormann et al. (2021). Our aim was to create a relevant set of literature and condense the core information from each publication. The systematic literature review consisted of three phases: first, generating a set of relevant publications following the PRISMA statement (Page et al. 2021), second, coding the literature using the software MAXQDA and third, analyzing the results. Using this method, we have identified all publications in which DPs have been developed, and systematic coding allows us to extract the design knowledge that has emerged.

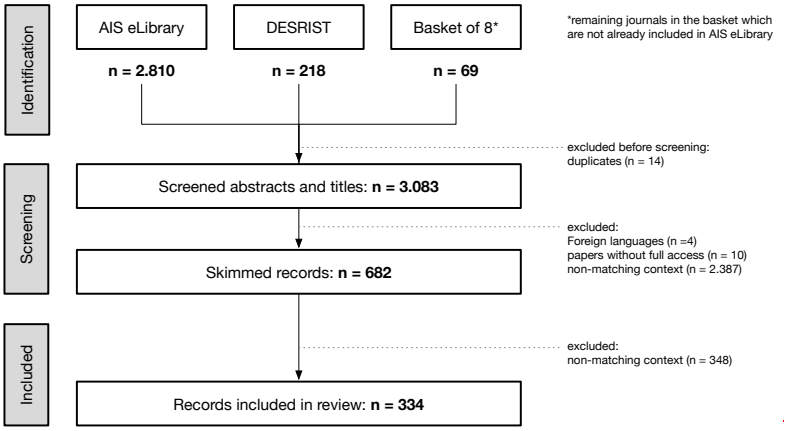

Figure 2. PRISMA flow diagram based on Page et al. (2021)

Figure 2 summarizes the first phase in a PRISMA flow diagram as proposed by Page et al. (2021). At first, we identified eligible scientific journal articles and conference papers by searching the chosen databases. Therefore, we referred to the AIS eLibrary as the central database for high-quality papers in the information systems research community and added the journals from the basket of eight (Senior Scholars' Basket of Journals, 2011). We began by searching the selected databases for relevant scientific journal articles and conference papers. As a result, we referred to the AIS eLibrary as the central database for high-quality papers in the information systems research community and added the eight journals from the Senior Scholars' Basket of Journals (Senior Scholars' Basket of Journals, 2011).

Furthermore, we included records published within the "International Conference on Design Science Research in IS" (DESRIST) which focuses specifically on DSR in IS and technology. The search was conducted in the beginning of December 2022. To construct the search phrase, we used the keyword "design principle" and two conceptualizations that are sometimes used interchangeably. This resulted in the following search query:

„design principle" OR „design guideline" OR „design pattern"

As we intended to examine the current state of research, we decided to focus on records published from 2011 onwards, thus using a filter on the results. In addition, we applied the search query only to the title, abstract, and keywords to limit the number of hits and with the assumption that publications that construct DPs also mention this in one of the three selected fields. With this limitation the search query resulted in 3.097 hits in total. Before moving on to the second step in the PRISMA-statement, the screening process, 14 duplicates were excluded. We then screened the abstracts and titles of the remaining 3.083 publications, thus identifying the first relevancy set. Criteria for excluding articles within the screening were: written in foreign languages other than English or German, without full paper access, non-matching context (not

using DSR, not deriving DPs). After the screening, 682 articles were chosen to move on to the next step where we skimmed the texts to further exclude results with non-matching context. The reasons for excluding papers from the review in this step were mainly that some authors referred to existing DPs from literature, others described their research in progress and did not derive DPs or did not apply DSR as a paradigm. In the end, this led to 334 papers which were moved to the second phase in our SLR.

We coded the publications iteratively by applying the qualitative content analysis according to Mayring (2022). The first iteration step was the actual identification of relevant papers, which is described above. Therefore, the categories "relevant" and "not relevant" were defined in advance based on our research question (Mayring 2022). The context unit, i.e., the largest text component that falls under a category, is here the complete paper (Mayring 2022). In the next iteration step, we used the software MAXQDA to code the relevant papers. The majority of the categories resulted from previous research methodology (vom Brocke et al. 2020; Gregor et al. 2020; Gregor and Hevner 2013; Gregor and Jones 2007; Möller et al. 2020), so we formulated them deductively. They are divided in main categories (application domain, construction, design knowledge) and subcategories (e.g., MR source, evaluation, user stories, MRs, DPs, design features). In the coding process we identified a lot of different forms of system classes and fields of application, so we condensed them into further subcategories like “conversational agents” or “healthcare”. Hence, this second level of subcategories were determined inductively from the material.

Since the majority of our coding system was established deductively and the main goal of our coding process was to systematically filter the text parts from the material which are addressed by our predefined categories, our procedure can largely be classified as content structuring, a content analytic technique introduced by Mayring (2022). Based on this method we have developed a coding manual. A coding manual is the key-element and the fundamental part of an analysis. Furthermore, it differentiates a content structuring from an open, interpretative text analysis (Mayring 2022). Nevertheless, the classification of the categories is a qualitative interpretative process, which at the same time is rule-guided by the coding manual. In this context, the development of a code manual first of all includes a definition of the categories (description of the text components that fall into a category), secondly the assignment of anchor examples which represent the specific categories (concrete text passages that fall under a category and are considered as examples for this category), thirdly the establishment of coding rules (formulation of rules for an unambiguous classification of related categories) (Mayring 2022).

Results

The coding system we used for the analysis during the coding stage of our research was divided into three overarching code categories: Application domain, construction, and design knowledge. Figure 3 shows an overview on the coding schema, giving an excerpt of the codes and corresponding subcodes. In sum, 98 codes were used, which were assigned 4305 times in total.

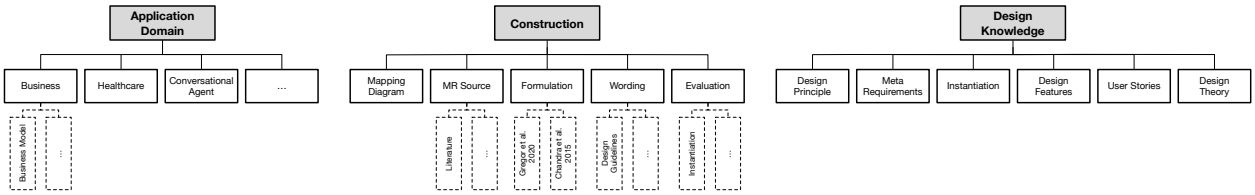

Figure 3. Coding Schema

Our analysis of the papers in the read set of the final stage of our literature review shows a significant increase in the number of publications that have constructed DPs over the past decade. All publications included in the final stage of our literature review can be viewed in the following digital appendix, a spreadsheet containing the year, author, and shortened title of the publication: https://bit.ly/dp-litrev-readset. Figure 4 shows an increasing trend in the number of DP-related publications from 2011 to 2022. Whereas in 2011 only four publications were identified (Chaturvedi et al. 2011; Derrick et al. 2011; Kohler et al. 2011; Pöppelbuß and Röglinger 2011), in 2022 there were already 64 publications. This trend shows that DPs have become an increasingly popular instrument for contributing abstract design knowledge. Its popularity may be due to the recognition in recent years of the significant contribution of design knowledge to IS research. It may also reflect that the construction and formulation of DPs has evolved over the years, as reported in previous studies (Gregor et al. 2020; Möller et al. 2020).

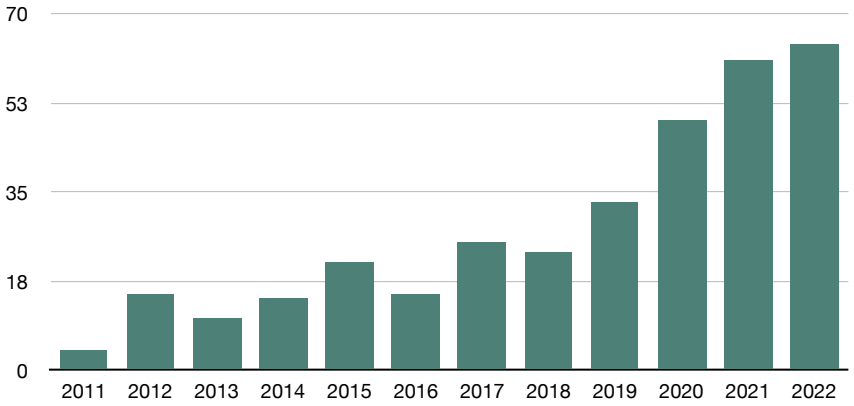

Figure 4. Publications per Year

During the coding we coded the different kinds of design knowledge that emerged throughout the publications. Our analysis shows that 327 sets of DPs were constructed, containing a total of 1990 singular entities. In addition, we found 152 sets of MRs, which contained a total of 1019 entities. We also found 34 sets of design features, containing 242 entities, and 14 sets of user stories, containing 136 entities. Of the 327 found sets of DPs 112 were also instantiated. This is quite interesting as it shows that the majority of the studies do not instantiate the abstract design knowledge. The instantiations were mostly documented by giving screenshots of the artefacts. Often hints were used to indicate which elements in the screenshots show which DP. Moreover, defining MRs has proven to be a suitable instrument for setting up the requirements for the meta-design, since about half of the publications do so. The MRs can have a variety of origins, whereas interviews and literature are the most popular ones: workshops (14), interviews (58), theory (14), literature (68). The definition of user stories is used as an instrument by 14 publications as an input for the MR formulation, e.g. Gebbing et al. (2022) or Meyer et al. (2022). 34 studies also give prescriptions about how to technically implement the abstract design knowledge in the form of design features, as conducted by e.g. Meth et al. (2015) or Feine et al. (2020). Seven of the publications go one step further and present the fully comprehensive design theory according to the anatomy of Gregor and Jones (2007), which contains several elements in addition to the set of DPs, e.g. in Morana et al. (2019) or Behrens et al. (2022).

Since we decided to also look for design guidelines and design patterns when setting up the search query, we also looked specifically at the possible wordings for the different forms of design knowledge. Nine publications contributed a set of design guidelines e.g. Strohmann et al. (2019) or Lins et al. (2019). Design patterns were not set up at all. We have included the design guidelines in the count of DPs, since they ended up being similar in nature and the wording and form did not differ much from the DPs. With regard to the wording of MRs, some studies have also called them design requirements.

	Number of Sets	**Number of entities**
DPs	327	1990
MRs	152	1019
Design Features	34	242
User Stories	14	136
Instantiations	-	112
Design Theories	-	7

Table 1. Design Knowledge

Publications such as Gregor et al. (2020) and Chandra et al. (2015) have provided guidance on the construction and formulation of DPs. However, we found that only a few publications have specifically used these guidelines in their construction and formulation of the DPs. Specifically, only seven publications used the anatomy of DPs by Gregor et al. (2020), e.g. Gerlach et al. (2022) or Weimann et al. (2022) and four

publications used the guidelines provided by Chandra et al. (2015), e.g. Feine et al. (2019). This suggests that while there are established guidelines available for constructing DPs, researchers may not be aware of them or may not be using them consistently.

On the other hand, we found that a relatively larger number of publications, 41 in total, used a mapping diagram to show the relationship between MRs, DPs, user stories or design features, e.g. Wambsganss et al. (2021) or Meth et al. (2015). This finding indicates that researchers may be more inclined to use tools that help them visualize the relationships between different forms of design knowledge.

With regard to the evaluation of DPs, the instantiation and testing of these, as well as expert and or user feedback have proven to be the most popular methods. While 138 publications instantiated their meta-design, most of them also tested their instantiation in an experiment. 77 studies have chosen expert or user feedback to evaluate their meta-design.

Our analysis shows that DPs have been developed for a wide range of application domains, which are presented in Figure 5. We identified 53 distinct domains in total. The highest number of publications constructed DPs for the business domain, followed by healthcare with 33 publications and conversational agents with 30 publications. Other top domains with more than nine publications were education/learning (18), collaboration/teams (12), service (12), finance (10), blockchain (9), decision support (9), process management (9), and sustainability (9). Concerning the business domain it has to be said, that it is a very broad domain, which is why we created subcodes identifying the more specific uses cases, such as business models (18), organization (8), business intelligence (8) enterprise systems (6), knowledge management (4), Enterprise Resource Planning (3) and several specific one like IT architecture, digital business, business reports, job skills, upskilling and value creation.

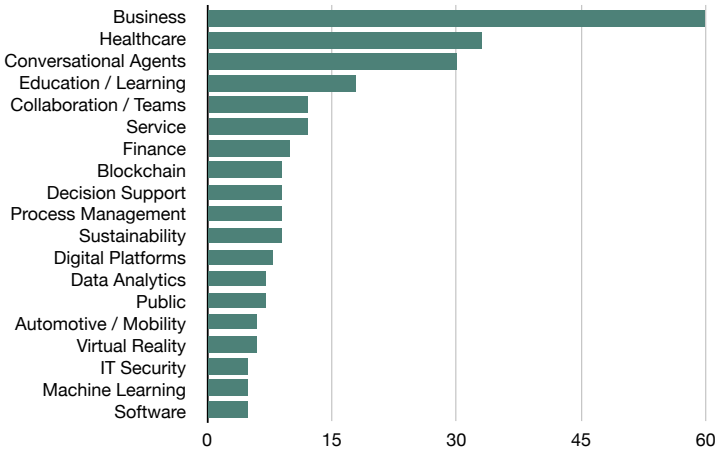

Figure 5. Application Domains (Number higher then 4)

Further application domains with eight or less sets of DPs are: digital platforms (8), data analytics (7), public (7), automotive/mobility (6), virtual reality (6), IT Security (5), machine learning (5), and software (5). Several domains had fewer sets of DPs, such as creativity and risk management (4), augmented reality, government, Internet-of-Things, and smart city (3), and cloud computing, commerce, digital transformation, emergency management, energy, IT governance, industry, nudging, recommendation systems, requirements, science, social, social media, and trust (2). Additionally, various domains had only one set of DPs: artificial intelligence, customer service, entertainment, gamification, IT support, innovation, logistics, production, project management, university, virtual worlds, wearables, and well-being.

Discussion

Our systematic literature review provides insights into the development and formulation of DPs in information systems research, highlighting the recent increase in the number of publications constructing sets of DPs in recent years.

Furthermore, our results uncover the wide range of application domains in which DPs have been constructed and applied. This demonstrates that DPs are an abstract representation of design knowledge that however always addresses a specific domain or context (zur Heiden 2020). This is especially important to distinguish a (nascent) design theory, that is more generalized, from DPs that target a more specific and explicit use case (problem space). Zur Heiden et al. (2020) distinguish between particularism and universalism when talking about the problem space or context. "Particularism acknowledges the context of research, whereas universalism aims to abstract theories to higher levels" (zur Heiden 2020, p. 1). Our results support this point by providing a concrete link to a context and use case of the sets of DPs.

Our analysis also reveals that there are established guidelines and tools available for the construction and formulation of DPs (Chandra et al. 2015; Gregor et al. 2020), but these may not be widely used by researchers. This suggests the need for greater awareness and adoption of these guidelines and structures to facilitate the construction of DPs in various application domains and make them accessible for both researchers to further develop and evaluate the DPs (Iivari et al. 2021) and practitioners (Chandra Kruse et al. 2022). In addition, our results further depict that the construction of DPs is often a non-systematic process, with synthesis and derivation from various findings and theories. Combining empirically captured user stories and kernel theories into MRs assists in the creation of DPs, ensuring rigorous development and traceability. Incorporating empirical requirements, such as user stories, highlights their relevance to the problem space. Visualization tools like mapping diagrams can effectively display the relationships between design knowledge forms, enabling a better understanding of DP relationships and underlying mechanisms. This ultimately leads to more effective IT artifacts development.

Our analysis shows that only about one-third of the DP sets have been instantiated. This amount indicates a significant gap between theory and practice (Siemon et al. 2022), as instantiated DPs can demonstrate the effectiveness and applicability of the abstract design knowledge to the real-world. Untested and uninstantiated DPs may have a limited impact or applicability (Chandra Kruse et al. 2022; Gregor et al. 2020). The low rate of DP instantiations may be attributed to factors such as unclear guidance, lack of implementation know-how, or researchers' disinterest. The popularity of creating DPs without instantiation may also be a trend. Design features can offer assumptions about potential instantiations of abstract design knowledge. Future research should investigate reasons for low implementation rates and develop strategies to address these barriers. Researchers should offer concrete methods for constructing and formulating DPs, including integration of upstream elements (justificatory knowledge, kernel theories, user stories, and MRs) and derivation of downstream aspects like design features and instantiations. While current research looks at isolated processes and presents guidelines and anatomies (Chandra Kruse et al. 2022; Gregor and Jones 2007; Iivari et al. 2021), a comprehensive approach encompassing DP derivation, instantiation, and evaluation, with all related concepts, is necessary.

Despite the valuable insights gained from our systematic literature review, our study also has limitations that should be considered. First, our analysis was limited to the information available in the publications included in our study. There may be other sources of design knowledge that are not published that could be considered in future research. Second, the design knowledge we extracted was analyzed at a high level and may not capture the nuance and complexity of the underlying concepts. Future research could examine the structure and composition of the extracted design knowledge in more detail to provide a more comprehensive understanding. Finally, our coding procedure was limited to predefined codes that may not capture all relevant information. A more detailed and comprehensive coding approach could provide further insight about the construction and formulation of design knowledge. These limitations highlight the need for further research to explore and refine our understanding of design knowledge and its role in information systems research.

Conclusions

In conclusion, our study addresses the RQ by uncovering key trends and implications of the evolving construction processes and forms of DPs in information systems research over the past decade. By understanding the nature and evolution of DPs, researchers can develop innovative and effective IT artifacts that solve real-world problems. The availability of established guidelines and tools for the construction and formulation of DPs, as well as visualization tools like mapping diagrams, can facilitate the development of high-quality DPs and further advance the field of information systems research.

The number of publications formulating DPs has increased significantly over the past decade. This trend indicates the growing importance of design knowledge in information systems research and highlights the need for continued research on the construction and formulation of DPs. Established guidelines and tools are available for the construction and formulation of DPs, but greater awareness and adoption of these structures are needed to facilitate their development and evaluation. The low rate of instantiation of DPs identified in our study highlights the need for greater attention and effort towards implementing and testing DPs in practice. Future research could focus on identifying and addressing the barriers to implementation and developing new strategies for testing and evaluating the effectiveness of DPs in real-world settings, leading to the development of more effective IT artifacts.

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