Design Science

Toward a general taxonomy of design computing research: a cross-conference analysis of research questions in recent proceedings

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Abstract

Design computing research, a subfield of design science, focuses on developing computational frameworks and tools for design-related activities. Growing interest in the field has resulted in an abundance of academic resources. To help researchers utilize these, we enumerate and organize the research questions pursued across design computing research, regardless of a specific design discipline or method. An existing taxonomy derived from a single venue (DCC) was applied to the recent proceedings of two additional venues (E&PDE, CAADRIA). This process has yielded a revised taxonomy that can account for the recent proceedings (2024) of all three conferences (N = 253), thus demonstrating potential for generalization. The taxonomy classifies works in the field into three major categories: (A) explanation of design-related activity, (B) application of knowledge for enhancing design-related activity, and (C) organization of knowledge on a meta-level. For each category, the corresponding questions and sub-questions are listed, and example papers are provided in the form of an index. A complementary computational exploration of clustering using machine learning has further highlighted the potential usefulness of the taxonomy. These categories can help researchers position their work in a broader context, support design computing pedagogy and help to create a map for the field.

Keywords: Design Computing and Cognition Conference (DCC), Engineering and Product Design Education Conference (E&PDE), Computer-Aided Architectural Design Research in Asia Conference (CAADRIA), Machine Learning, Meta-Level Mapping, Systematic Review

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1. Introduction

Recent years have seen an increased interest in systematic reviews of scientific literature. This interest reflects our need for resources that can help utilize the plethora of information available for review. Researchers working in design computing, a rapidly growing field, stand to greatly benefit from such resources in making sense of the scientific landscape. As identifying relationships is fundamental to sensemaking (Klein, Moon & Hoffman 2006), we set out to identify the shared themes underlying design computing research. Table 1 lists several

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Table 1. Examples of potential classification dimensions

Dimension	Example	Advantage	Disadvantage
Tool	Rhinoceros 3D	Clearly identifiable	Not all studies employ tools
Method	Protocol analysis	Clearly identifiable, core component of scientific activity	May quickly become outdated
Approach	Shape grammar	Acknowledges the existence of sub-communities within the field	Relationship with works outside of the sub-community remains hidden
Purpose	Understand how designers perceive tools	Implicitly defines sub-communities by shared purpose; can expose similarities among seemingly unrelated works	Not always explicitly mentioned

dimensions that may serve as the basis for grouping research works, along with some of their advantages and disadvantages.

As shown in Table 1, the 'purpose' dimension can serve as a useful device for organizing works in the field. However, organizing works by their purpose is a challenging task, as purposes are often implicit and thus require extraction. In this work, we attempt to identify the purposes of research works and use them to organize the field. To extract the purpose of a research work, we focus on the research question pursued as a proxy for the underlying purpose.

Research questions are fundamental to any research activity and can potentially reveal links between seemingly unrelated works (e.g., two researchers may employ different methods to answer the same question and may thus have a shared purpose). Our primary objective is to expose common questions that are explored by researchers, regardless of any specific design domain, technology or method. Therefore, our research question is: What **questions are currently being explored by design computing researchers across the field?**

A taxonomy for organizing research works in design computing was recently proposed by Kahlon & Fujii (2025), based on the complete proceedings of a single international conference (Design Computing and Cognition; DCC). This taxonomy can serve as a springboard for mapping the broader field of design computing, but its applicability beyond the conference remains to be examined. In this article, we apply the above taxonomy to the recent proceedings (2024) of two other major conferences in the field, focusing on (1) architectural design (CAADRIA) and (2) engineering and product design education (E&PDE). The choice to focus on recent works is motivated by the fact that technological developments give birth to new questions more often than they eradicate older ones. For example, before the advent of computer systems, questions regarding best practices in utilizing these systems could not arise. However, decades after the introduction of computational tools into design, manual design processes (e.g., sketching on paper) continue to be of interest to researchers (in tandem with more recent practices such as digital sketching).

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The result of our analysis is a revised taxonomy that helps organize the questions pursued by researchers in design computing and is grounded in hundreds of research works. To help utilize this classification system, we provide an index of research works associated with each of the questions identified.

Researchers in design computing can use our findings to explore the gamut of questions pursued by other researchers in the field, as well as to retrieve example papers focusing on their question/s of interest. Relatedly, educators can use the proposed classification system for providing an overview of the overarching themes in the field, as well as recommend readings based on specific research questions. Finally, the dataset produced by this investigation may be useful for developing AI models for automating the classification of research works based on the questions pursued.

2. Background

2.1. Design computing

Fundamentally, design computing includes three kinds of activities: practice, research and pedagogy (Gero & Maher 1997). Design computing research strives to produce knowledge (models/frameworks) and tools that can be employed in design computing practice, while design computing pedagogy focuses on utilizing such knowledge and tools for educating our future designers and researchers. The relation between these activities is conceptualized below (Figure 1). This work contributes to a better understanding of the landscape of design computing research activity.

Design computing is a cross-disciplinary endeavor. Historically, the field was strongly associated with architectural design. For example, the pioneering Key Center for Design Computing and Cognition at the University of Sydney (established in the late 1960s) was situated within the institute's School of *Architecture*, Design and Planning. Also, Johnson's (2016) well-known overview of design computing has framed it as a discipline that links computer science, design, and the *built environment*. Academic literature, however, shows that the field encompasses a wide range of domains, e.g., product design (McKay *et al.* 2006), graphic design (Bokil 2015), engineering design (Fitzhorn 1994), service design (Kannengiesser & Gero 2015), interaction design (Hu *et al.* 2023), fashion design (Lee, Yang & Sun 2021) and more.

2.2. Making sense of design computing research

Works providing an overview of design computing practice can be found (Johnson 2016). However, works that provide us with an overview of the field of design computing *research* are scarce. Therefore, it is important to expand our body of knowledge concerning the structure of design computing research.

In 1997, Gero and Maher laid the groundwork for organizing design computing research by identifying three main goals in the field (1997): (1) to develop theories and models of design processes, (2) to utilize the output of 1 for creating design tools and (3) to utilize the output of 1 for design education. This framework was recently used by Kahlon & Fujii (2025) for extracting a set of research questions that are shared among works in the field, resulting in a taxonomy consisting of five

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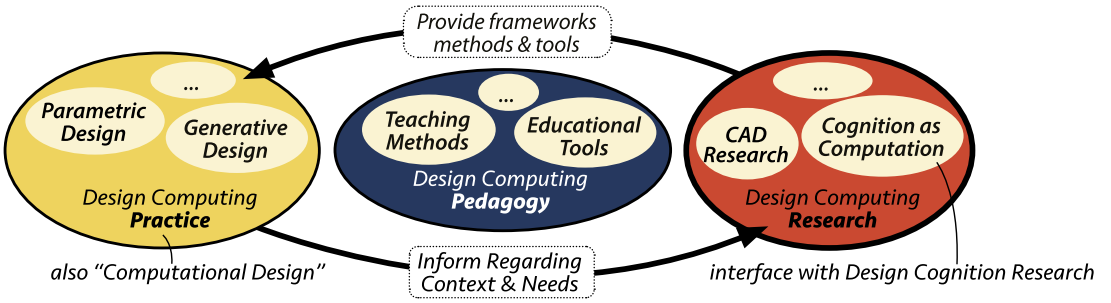


Figure 1. Conceptualizing the landscape of design computing.

overarching questions and 20 sub-questions. The questions identified there can help create a general map for the field. However, as the above taxonomy was derived from a single international conference, it is essential to examine its generalizability for the proceedings of additional conferences, communities and so forth. To do so, we apply their taxonomy to two other international conferences and then reorganize it, as needed, to encompass a larger number of research works in the broader field.

2.3. Manually extracting research questions from design computing literature

Considering the plethora of articles and materials available, comprehensively mapping research questions in the field would demand automation. Indeed, computational tools have been used for literature reviews in design computing. For instance, Bhatt & Martens (2006) have attempted to map the activity in computer-aided architectural design research, a subset of design computing research, by visualizing relationships between concepts in the form of a network, based on an analysis of 3,000 papers. Additional examples can be found in Topuz & Çakici Alp (2023), who have investigated the usage of programming languages and algorithms in the context of architectural design research, as well as in Kahlon, McComb & Fujii (2025), who have explored chronological changes across the proceedings of a given conference via supervised machine learning.

Evidently, there are major benefits of using computational tools in literature reviews, as these allow researchers to:

- Process extremely large amounts of information, as demonstrated by Bhatt & Martens' work (2006), which synthesized thousands of records
- Minimize error in analysis processes that focus on the technical details of the investigation (keywords, year of publication, etc.), as reflected in the study by Topuz & Çakici Alp (2023).
- Generalize insights from small sets of samples to larger ones, as demonstrated by Kahlon, McComb & Fujii (2025)

Despite these benefits of using computational approaches for literature reviews, classifying works by their shared research question is computationally difficult for multiple reasons:

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- Articles do not always specify their research question(s) explicitly, so that effective extraction depends on the ability of a human reader to derive it via conceptual "reverse engineering"
- Even when the questions addressed are stated explicitly, their level of abstraction can hide commonalities between related questions—consider *"(how can we) allow end users to personalize their tableware sets, namely to determine the shape of its elements (?)"* (Costa & Duarte 2015, p. 437) and "*…how the extraction and presentation of patent data could be improved for designers (?)*" (Vasantha *et al.* 2017, p. 209), which are instances of '*how can we build better digital tools for supporting design practice?*'
- Utilizing supervised machine learning requires us to manually produce training data that matches research works with the questions pursued (currently unavailable)
- Utilizing unsupervised machine learning may produce clusters of works based on dimensions that are not necessarily intelligible for human researchers (Hu *et al.* 2026), and thus require further interpretation according to an existing framework

Therefore, human annotation of a large number of research works can help organize the field in at least three ways: (1) by providing a taxonomy for classifying research works which can serve as a baseline for further manual classification, (2) by providing a means for interpreting the results of automated clustering and (3) by producing data for training models via supervised learning techniques, to help automate the process of classifying works in the future.

3. Aim and significance

Our research aims to help researchers and educators navigate the landscape of design computing research. This article offers (1) a taxonomy for classifying works in design computing research by their research question that is potentially generalizable to a large number of papers and (2) an index listing example papers. These provide an overview of the current activity in design computing research and can help retrieve specific works based on one's goals/interests.

4. Method

A taxonomy for organizing works in design computing by their research question was developed by Kahlon & Fujii (2025), based on previous work by Gero & Maher (1997). The taxonomy proposed by Kahlon & Fujii (Table 2), which organizes the field into five overarching questions and 20 sub-questions, was derived from a survey of a single conference. To examine its potential for generalization, we apply it to the recent proceedings (2024) of two other well-known international conferences in the field, then reorganize it to account for the complete set of papers surveyed.

To structure our survey, we draw on PRISMA and organize the activity into two stages of paper selection (which further involves retrieval, screening, and determination of eligibility) and classification and synthesis. PRISMA is an approach for systematizing academic literature reviews by providing researchers with a set of preferred reporting items (Page *et al.* 2021). This approach has been applied in a wide range of disciplines (Pritchett, Gillberg & Minnis 2013; O'Dea *et al.* 2021;

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Table 2. Overview of the taxonomy used in this study for classifying research works (Kahlon & Fujii 2025)

ID	Overarching questions (how can we…)	Examples for sub-question (how can we…)
A	…organize our knowledge in design computing research?	…organize our knowledge concerning the explanation of design as a process?
B	…explain designing from a computational perspective?	…develop our lens for looking at design activity?
C	…enhance our methods of designing?	…improve our existing methods?
D	…use our understanding of designing as computation to build computational tools for design-related activity?	…build tools for supporting design practice?
E	…use our understanding of designing as computation for design pedagogy?	…use computational approaches in design pedagogy?

How, Tan & Miksza 2022; Sirisha *et al.* 2025), including design (Hay *et al.* 2017; C. Valentine 2024).

Furthermore, to complement our manual survey, we applied a computational approach to explore the automated clustering of works based on their full-text content. PDFs of all eligible papers were embedded using the SPECTER2 language model (Singh *et al.* 2022), reduced in dimensionality with t-SNE, and clustered using HDBSCAN (Campello, Moulavi & Sander 2013). The resulting data-driven clusters were compared with our manual classification to assess alignment and examine the potential for semi-automated mapping of the field.

The rest of this section is organized as follows. First, we describe the processes of paper selection (Section 4.1) and classification and synthesis (Section 4.2). Then we elaborate on the computational approach used for exploring clusters of papers and the ways it was employed to detect groups of works in design computing research (Section 4.3).

4.1. Paper selection

When selecting our target venues, we have considered the distribution of literature in the field across different design domains. An examination of Google Scholar search results across seven design domains (Table 3) shows that over 75% of the literature indexed by the search engine is associated with the following three domains: architectural design, engineering design, and product design. Therefore, these domains must be considered in paper selection. Accordingly, in addition to the DCC conference surveyed in the original work (Kahlon & Fujii 2025), we have surveyed the recent proceedings (2024) of the following international conferences:

- Computer-Aided Architectural Design Research in Asia (CAADRIA); representative of architectural design
- Engineering and Product Design Education (E&PDE); representative of engineering and product design

While no manual survey can feasibly cover the complete range of questions pursued in the field, our choice of venues can be seen as a reasonably representative

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Table 3. Distribution of design computing literature by design domain based on Google Scholar search results

Design domain	Search string	Items (*N*=)	% of Total
Architectural design	"design computing" AND "architectural design"	4690	30.1
Engineering design	"design computing" AND "engineering design"	4590	29.4
Product design	"design computing" AND "product design"	2740	17.6
Urban design	"design computing" AND "urban design"	1320	8.5
Graphic design	"design computing" AND "graphic design"	707	4.5
Service design	"design computing" AND "service design"	293	1.9
Fashion design	"design computing" AND "fashion design"	234	1.5
Total items	"design computing"	15,600	

sample, for several reasons. First, as noted above, the conferences include literature concerning all three major categories of architectural design (CAADRIA), engineering design, and product design (both E&PDE), as well as literature that is interdisciplinary in nature (DCC). Second, considering that design computing includes activities of research, practice, and pedagogy (Gero & Maher 1997), surveys of design computing research should include both works concerning practice and pedagogy. This is reflected in the inclusion of both CAADRIA (largely practice-oriented) and that of E&PDE (largely pedagogy-oriented). Finally, our focus on recent literature is motivated by the fact that development in research often results in opening new venues of inquiry, thus expanding the range of questions that can be asked. For example, prior to the advent of generative artificial intelligence, questions concerning the usefulness of such systems for designing could not arise. By contrast, older questions concerning the nature of manual designing continue to be of interest to researchers, despite the development of new tools and methods.

At the initial stage of the selection process, all items were screened to identify those which are not full research/review papers (e.g., abstracts, workshop proposals, etc.), resulting in the removal of one item.

Next, considering that the conferences under consideration are not restricted to design computing, we set out to determine the eligibility of each of the remaining items based on the following criterion: has the paper made a direct contribution to design computing research? A direct contribution was defined as creating/extending/applying a computational framework, model or tool in any design-related activity. This criterion enabled us to (1) include a diverse range of contributions that are directly relevant to the field and (2) only exclude those containing findings that require additional interpretation or mobilization to be regarded as relevant to design computing research. For example, records that dealt with teaching using computational tools without reference to designing (e.g., Kröpfl, Ortner-Pichler & Landschützer 2024) were excluded. However, related records that explicitly linked their investigation with designing, e.g., the work by Barrie (2024) that focused on design activity in the context of engineering design, were included. Additionally, if a single record reported on more than one investigation, each was regarded

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Table 4. Focused conferences and the number of papers selected from each

Conference (ordered alphabetically)	Focus/domain	Total items in 2024	Items screened	Items excluded by eligibility	Items included
CAADRIA	Architecture	161	1	1	159
DCC	Design computing & cognition	33	0	3	30
E&PDE	Eng. & product design education	118	0	54	64
Grand total		312	1	58	**253**



Figure 2. Paper selection process.

separately when extracting research questions. For example, Tunçer *et al.* have reported on a survey *and* on an experiment in Virtual Reality (VR). As the former was not deemed a direct contribution, only the latter activity (that involves the usage of a computational tool for hypothesis testing) was included in this survey.

In both stages of screening and determining eligibility, we first examined the title and abstract of the record, then confirmed or altered our decision by consulting its full text. The exact number of records selected from each conference is given in Table 4, and the complete process of paper selection described above is summarized in Figure 2.

4.2. Classification and synthesis

Classification was conducted by a specialist in design computing with over a decade of experience in research and practice activities, spanning multiple disciplines and scales (architectural design, industrial design and interaction design), thus mitigating the bias associated with working in a single discipline. Boundary cases in which deliberation was required were decided following a discussion between the coder and a senior researcher in design computing with over 30 years of experience in the field (both parties are among the co-authors of this work).

Deliberation proceeded as follows: (1) introducing the full text of the record under consideration; (2) introducing one or more questions that can potentially match with it, the reasons for selecting these, and the difficulties that arise when attempting to assign each; (3) receiving feedback concerning the fit between the record and the questions under consideration, which confirms/rejects/reassigns a question to the

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record. Disagreements were resolved through a simple process of adjudication: (1) for a given question q', revisit its fit by stepping up to a higher-level question q and examining its fit with the record; (2) consider reassignment to another higher-level question or lower-level question through deliberation until agreement is reached; (3) if different questions were assigned to the record and no agreement could be reached, both questions were maintained as valid matches, to err on the side of inclusion.

The processes of classification and synthesis were done in four stages: (1) extraction of research questions, (2) matching extracted research questions with the existing classification system, (3) revision of the classification system based on new findings and (4) visualization of the classification results and organization in the form of an index. Each of these four stages is elaborated below. Figure 3 summarizes and illustrates the entire classification procedure for clarity and reproducibility. As the classification process is iterative by nature, the reader should bear in mind that certain steps may be executed multiple times per item.

In Stage 1, we set out to extract the primary research questions pursued in the record under consideration. In cases where the question pursued was not explicitly stated by the authors, we turned to the claimed goal/objective/aim of the authors. If neither was clearly mentioned, the full text of the paper was used to extract the questions pursued by identifying the primary issue, which was elucidated by the paper. Whether the question was explicitly stated or derived, its coherence with the full text of the paper was confirmed prior to making our decision. Note that certain studies pursued more than one question. For example, the work by Wu *et al.* has dealt with the improvement of an existing ontology that helps describe designing as a form of computation, as well as with the development of a tool using this ontology (2024). Therefore, it was matched with two questions – 'How *can we develop our lens for looking at designing?*' and 'How *can we build tools for supporting design practice?*' – accordingly.

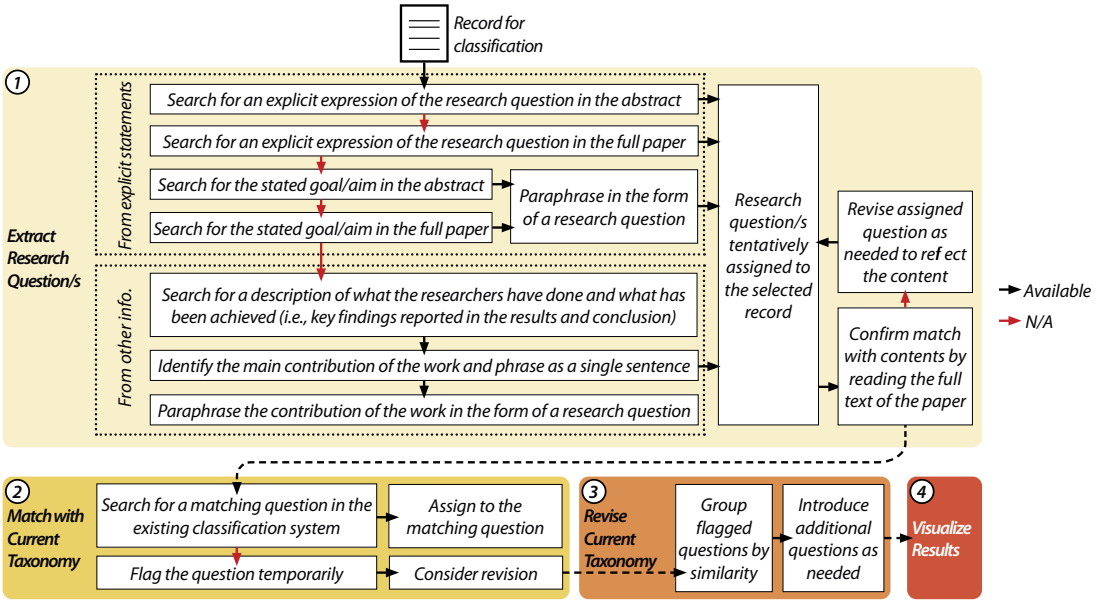


Figure 3. Paper classification and synthesis process.

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In Stage 2, the research questions extracted at the previous stage were matched with the list of questions identified by Kahlon & Fujii (2025, p. 22). As mentioned above, certain studies pursued more than one question. Therefore, multi-label assignment was allowed. For each study, we first attempted to match its extracted question(s) with one of the five overarching questions (A, B, C, D or E) and then with its sub-questions. To do so, it was occasionally essential to rephrase the extracted question at a different level of abstraction to enable matching with the questions in the current taxonomy. For example, the specific question of 'What *is the influence of the level of abstraction of a stimulus on creativity as reflected in designers' brain activity?*' explored by Wang *et al.* (2024a) can be seen as an instance of the more general question of 'How *can we use computational tools for studying design cognition phenomena?*' *etc*.

In Stage 3, under the assumption that not all records necessarily fit within the current taxonomy, papers pursuing questions that lacked a clear match were flagged, and notes concerning possible revisions to the taxonomy were taken. Then, similar papers were grouped and used to suggest modifications/additions to the taxonomy. This enabled us to reconsider the current taxonomy to better capture the diverse activity in the field.

In Stage 4, we visualized the results of the classification process to reflect the distribution of research questions pursued, both within each conference and overall. This yielded a useful overview of the questions examined by researchers. Additionally, we have organized the results of the classification in the form of a simple index by listing one study for each question pursued, as well as providing the complete results in Appendix A.

Finally, to examine the reliability of classification, we have executed a post-hoc blind audit on a sample of 14% of the selected records ($N = 36/253$), extracted using stratified random sampling ($N = 12$ from each venue). The sampled records were reclassified by the same coder after a washout period exceeding six months, thus mitigating the effect of recall on reclassification. Agreement between originally assigned categories and re-assigned ones was measured using percentage agreement while considering the results of all three subtasks involved in the classification process (assigning an overarching question, assigning a sub-question, and assigning a sub-sub-question). For each subtask, we calculated two scores. First, an *absolute misalignment* rate was calculated, reflecting the number of records that were misclassified out of the total number of records in the audit. Second, an *alignment score* was calculated to consider the fact that alignment of the results can be partial due to multi-label classification. The alignment score was calculated as $(A + (B + C + D) * 0.5)/N$, where A represents the total number of records that were precisely aligned, B and C represent the possibility of one set of assigned categories containing another (e.g., question X was assigned to a record once, then questions X and Y were assigned to it later), D represents a partial overlap (e.g., questions X and Y were assigned to a record once, while questions Y and Z were assigned to it later), and N is the total number of papers reclassified in the audit.

4.3 Exploratory computational clustering using machine learning

In parallel with the manual classification, we conducted a computational analysis to investigate the potential for automated clustering of the records.

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Full-text content was extracted from the PDFs of all eligible records and embedded using the SPECTER2 language model (Singh *et al.* 2022). We selected SPECTER2 because it is designed for scholarly-document representation and thus provides a reasonable off-the-shelf basis for measuring similarity among records in the exploratory clustering analysis performed here. The resulting embeddings were reduced in dimensionality using t-distributed stochastic neighbor embedding (t-SNE). To identify groups of similar records, we applied the HDBSCAN clustering algorithm to the high-dimensional embeddings, allowing as few as 2 samples per cluster (although this limit was not reached). The remaining parameters were left at library defaults (Campello *et al.* 2013).

This process provided an additional, independent perspective on the thematic structure of the record set, allowing us to compare and contrast human-coded categories with algorithmically discovered clusters and to consider the implications for semi-automated mapping of the design computing research landscape.

5. Results

The processes of classification and synthesis have yielded three overarching categories for classifying research questions in design computing research. In the following subsections we present each category in detail, including the questions and sub-questions associated with it (Sections 5.1–5.3). We provide ample examples by referring to papers in our sample, including at least one example from each conference surveyed, where available.

Concerning the results reported in Sections 5.1–5.3, agreement rates between the original classification process and the post-hoc audit were as follows. On the subtask of classifying records by the overarching question pursued, absolute misalignment stood at ~8.33%, and the overall alignment score was ~86.1%. On the lower-level task of classifying records by sub-questions, absolute misalignment was similar (~8.33%), and the alignment score was slightly lower than in the previous subtask (80.55%). Finally, on the lowest-level classification subtask of classifying records by sub-sub-questions, absolute misalignment was highest (~13.88%), and the alignment score was lowest, yet remained at an acceptable level considering the complexity of the classification task (~70.83%).

The results reported in Sections 5.1–5.3 are then synthesized in the form of a taxonomy for classifying research works in design computing, given in Section 5.4. After presenting the taxonomy, we elaborate on its relationship with past taxonomies, which helped develop it. Finally, we present the results from our computational exploration of automated clustering using machine learning (Section 5.5).

5.1 Category A – explaining design-related activities

Work in this category focuses on obtaining new knowledge concerning the explanation of design phenomena, including how human designers engage in designing, how we teach or learn to design, and more. The general question that unites works in this category is—how *can we explain design-related phenomena from the standpoint of design computing research?* This question is then elaborated into two primary sub-questions, focusing on the explanation of design practice and of design pedagogy. We elaborate on each of these in Sections 5.1.1 and 5.1.2, respectively. An overview of this category is given in Table 5.

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Table 5. Overview of questions pursued in category A

Purpose	Questions	Sub-questions
Explanation of design-related phenomena	*How can we **understand design practice** from the standpoint of design computing research?*	*How can we **develop our lens** for **describing designing** as a form of computation?*
		*How can we **build** computational **tools** for **inquiry into design**?*
		*How can we **use our lenses and tools to study designing** from a computational perspective?*
	*How can we **understand design pedagogy** from the standpoint of design computing research?*	*How can we **use our lenses and tools to study design pedagogy** from a computational perspective?*

5.1.1. Explanation of design practice

The first sub-question in category A reflects our desire to understand how we engage in designing—how *can we understand design practice from the standpoint of design computing research?* This includes the explanation of designing with computational tools, as well as the application of computational tools or approaches for explaining design activity. **Three sub-questions** are nested under this question.

First, certain works help develop our ways of viewing design activity—how *can we develop our lens for looking at designing from a computational perspective?* For example, Lim (2024) has proposed a framework for conceptualizing the usage of AI tools in designing ("seeing-instructing-seeing"), based on interviews held with design professionals and experiments with novice designers. Relatedly, Urquhart, Petrakis & Wodehouse (2024) have proposed a framework for understanding users' engagement with digital tools ("orders of engagement") as a basis for enhancing interaction design practices.

Second, researchers are creating tools for augmenting our ability to study design—how *can we build computational tools for inquiry into design?* For example, Yildirim *et al.* (2024) have explored the augmentation of virtual reality (VR) space with smell to enhance our ability to study users' responses to multi-sensory architectural environments. Relatedly, the visualization tool proposed by Paravizo & Crilly (2024) for exploring design spaces can be utilized for design cognition research.

Third, the theoretical lenses and tools developed by researchers pursuing the above questions are applied for the purpose of explaining design activity—how *can we use our lenses and tools to study designing from a computational perspective?* Here, we distinguish between testing hypotheses *by employing* computational approaches and tools and testing hypotheses *about computational tools*. As examples for testing hypotheses via computational approaches and tools, consider the work by Kelly *et al.* (2024), who have applied linkography (Goldschmidt 2014) in conjunction with knowledge concerning framing (Dorst 2015) to visualize framing activity in designing based on protocols; the work by Shi &

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Economou (2024), who have applied the lens of shape grammar (Stiny 1980) to formally represent a traditional Chinese architectural element; the work by Huang, Song & Qiu (2024), who have analyzed the relationships between environmental attributes and cycling behavior using linear and spatial regression models; and the work by Sitarama & Agogino (2024), who have tried to predict the success of product design teams from design data by computing a newly proposed index ("creative tension balance") for measuring team performance. As examples for testing hypotheses about computational tools, Arisman *et al.* (2024) have examined the usage of generative design for the purpose of form finding among architects at the schematic design stage, and Rodriguez-Ferradas *et al.* (2024) have studied the application of AI tools in industrial design. Relatedly, focusing on the usage of generative AI by designers, D'souza & Dastmalchi (2024) have studied the relationship between prompts and the production of creative output.

5.1.2. Explanation of design pedagogy

The second sub-question in category A reflects our desire to understand how we engage in design pedagogy—how *can we understand design pedagogy from the standpoint of design computing research?* Surveyed papers in this category have focused on the more specific question—how *can we use our lenses and tools to study design pedagogy from a computational perspective?* As with the corresponding sub-question in Section 5.1.1, we distinguish between studying design pedagogy by using computational tools and studying design pedagogy focusing on the usage of tools. Concerning the former, the tool developed by Paravizo & Crilly (2024) mentioned earlier was also suggested as a means for inquiring into human cognition in design pedagogy. Concerning the latter, computational tools often change the ways in which we teach and learn, which prompts the study of these changes. For example, Loh & Jahn (2024) have reported on a case study of using Augmented Reality (AR) technology in architectural design education to examine its impact on the process of designing and fabricating a room-scale installation. Additionally, Bartlett, Mills & Hagins (2024) have studied the effectiveness of AI-powered sketching tools in helping students generate concepts with a high degree of legibility; Jiménez Romanillos & Andersson (2024) have used Bloom's taxonomy (1964) to learn about the usage of AI tools by students in a product development course; and Chen, Lucchini & Simpson (2024) have observed students' usage of AI tools for producing culturally relevant designs. Such studies occasionally focus on understanding users' perceptions regarding computational tools. For instance, Koolman *et al.* (2025) have studied the attitudes of students toward various design approaches, including computational and non-computational ones.

5.2. Category B – applying our knowledge for enhancing design-related activities

Works in this category focus on utilizing the knowledge produced in category A and organized in category C for enhancing our tools and practices. The general question that binds works in this category is—how *can we apply our knowledge in design computing research to enhance our future tools and practices?* This question

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Table 6. Overview of category B

Purpose	Questions	Sub-questions
Apply the knowledge in design computing to **enhance** our **future tools and practices**	*How can we **apply** our knowledge in design computing research for **enhancing design practice?***	*How can we **use** our current computational **approaches/tools** in **design practice**?*
		*How can we **create new** approaches/tools for **design practice**?*
	*How can we **apply** our knowledge in design computing research for **enhancing design pedagogy?***	*How can we **use** our current computational **approaches/tools** in **pedagogy**?*
		*How can we **create new** approaches/tools for **design pedagogy**?*

is then elaborated into two sub-questions, given in Sections 5.2.1 and 5.2.2, respectively. An overview of this category is given in Table 6.

5.2.1. Applying our knowledge for enhancing design practice

The first sub-question in category B reflects our desire to enhance our design-related practices—how *can we apply our knowledge in design computing research for enhancing design practice?* The two questions nested under this question are presented below.

First, researchers are using our existing approaches and tools to enhance design—how *can we use our current computational approaches/tools in design practice?* For example, Jowers, Clarke & Moat (2024) have used structural simulation for creating a "catalog" that helps match variations of honeycomb-shaped designs with their structural performance. Such a catalog expands our body of knowledge concerning the behavior of complex geometry, which can inform its application in design. While the previous example shows how a tool can be utilized to expand our body of knowledge concerning design, researchers are also producing knowledge concerning the usage of the tools themselves. For instance, Feng *et al.* (2024) have proposed a way to make efficient use of Large Language Models (LLMs) by prompting them with personas, thereby helping designers to increase the diversity of output when using this technology. Relatedly, R. Valentine (2024) explored prompt engineering for utilizing AI in product design. Additionally, Sun, Meng & Wang (2024) have highlighted the limitations of applying various indices for measuring the compactness of urban form in different settings and matched each with a scenario in which it is effective. A further distinction can be made between developing our practices of designing *with* computational tools (described thus far) and those for the design *of* artifacts that include a computational component. As an example for the latter, consider the study by Lai (2024), who has explored the construction of an architectural element that responds to the users' emotional state.

Second, the development of computational tools opens new possibilities for designing—how *can we develop new practices through computation*? For example,

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Guo *et al.* (2024) have proposed a brain-computer interface for interactive spatial design using an electroencephalogram (EEG). As design is increasingly becoming interlinked with fabrication processes, the phrase "new practices" should be understood in a broad sense, which includes the conversion of design documentation (Gero 1990) to physical prototypes. For example, Benros, Hashemi & Su (2024) have implemented a shape grammar to streamline the process of architectural design and fabrication using robotic extrusion, then used it for the construction of a physical micro-house. Relatedly, Skevaki *et al.* (2024) have proposed an interactive workflow for the design and fabrication of timber assemblies, which facilitates effective human-robot collaboration.

5.2.2. *Applying our knowledge for enhancing design pedagogy*

The second sub-question of category B reflects our desire to enhance our design pedagogy—how *can we apply our knowledge in design computing research for enhancing design pedagogy?* The two questions nested under this sub-question are presented below.

First, to utilize developments in design computing for the benefit of design pedagogy, we must produce knowledge concerning the utilization of existing/emerging tools and approaches—how *can we use our current computational approaches/tools in pedagogy?* Typical studies suggest ways to reconsider/adapt our curricula considering the technological developments. For example, Barrie (2024) has questioned the relevance of traditional technical drawing practices in the current age, Calixto & Croffi (2024) have proposed a framework for teaching computational design to undergraduate and graduate students, Contreras Garcia (2024) has attempted to integrate VR into a first-year product design class, and more. Beyond content-focused adaptations to curricula, effective ways to utilize computational tools for the benefit of pedagogy are also being proposed. For example, Silva *et al.* (2024) have proposed ways to help reduce bias among learners when using generative AI, thereby facilitating ethical usage in educational environments.

Second, we can also enhance design pedagogy by developing computational tools/approaches to support teaching and learning—how *can we create new approaches/tools for design pedagogy?* For example, Hadiatmadja (2024) proposed the possibility of augmenting digital design education in architecture using an AI-powered conversational avatar. Relatedly, an AI-driven system for personalized learning of CAD was proposed by Kravchenko & Green (2024). Additionally, Kelly *et al.* (2024) have proposed an approach for automatically visualizing information concerning design cognition in near-real-time, which is potentially applicable for supporting design pedagogy.

5.3. Category C—organizing our knowledge in design computing research on a meta-level

Work in this category focuses on the organization of knowledge in design computing research, to bring clarity regarding our current understanding, expose research gaps, synthesize findings, and more. The general question that unites works in this category is: *how can we organize our knowledge in design computing research?* This question is then elaborated into three sub-questions, as explained

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Table 7. Overview of category C

Purpose	Questions	Sub-questions
Organize our knowledge in the field	*How can we **organize our knowledge** in design computing research?*	*How can we **organize** knowledge concerning the **explanation of design-related activities**?* *How can we **organize knowledge** concerning the **enhancement of design-related activities**?* *How can we **organize knowledge** concerning **the structure of the field as a whole**?*

hereafter. An overview of this category is given at the end of this subsection in Table 7.

First, certain works survey our knowledge regarding the explanation of design-related phenomena—how *can we organize our knowledge concerning the explanation of design-related activities?* For instance, to help study design creativity, Wang *et al.* (2024b) reported on a PRISMA review of papers in which EEG was employed for this purpose and highlighted the neurocognitive indices that may be used by such studies. Note that "design-related activities" encompass design practice, design pedagogy, as well as other activities (marketing, management, etc.).

Second, meta-level research is being conducted focusing on developing and applying better practices and tools—how *can we organize knowledge concerning the enhancement of design-related activities?* An example is the work by Bordas *et al.* (2024), who have examined the literature on generative artificial intelligence to provide an overview of the content that can be generated by these tools in design. Further, in the context of tools for the architecture, engineering, and construction industry (AEC), Rafizadeh *et al.* (2024) have proposed a taxonomy for organizing the kinds of automation enabled by computational tools. Moreover, to support the navigation of design spaces, Paravizo & Crilly (2024) have reviewed existing studies on design space representation. Finally, to shed light on the roles of AI in the context of design education, Ge & Fan (2024) have surveyed the literature on using AI in design pedagogy, as reflected in the perceptions of educators.

Third, researchers are also attempting to describe the overarching structure of the field itself—how *can we organize our knowledge concerning the field as a whole?* Works pursuing this question strive to identify relationships, hierarchies, etc., among diverse sets of papers and articles. For example, Kahlon & Fujii (2024) have surveyed and classified the complete proceedings of an international conference (DCC) to map the shared themes that unite diverse works.

5.4 Proposing a taxonomy for classifying research works in design computing

Synthesis of the research questions identified has resulted in a revised taxonomy for classifying questions in design computing research. An overview of the revised taxonomy is given in Table 8, and a detailed version, which includes all sub-questions and example papers, is given in Table 9. These tables are followed by key

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Table 8. Three activities in design computing research

ID	Name	Purpose	Type of activity
A	Explanation	Explaining any design-related activity	Research
B	Application	Applying our knowledge for enhancing design-related activity	
C	Organization	Organizing our knowledge in the field	Meta-research

statistics regarding the distribution of papers surveyed across the research questions identified. The complete mapping of all surveyed papers onto the research questions pursued is provided in Appendix A (Table A1), which employs the same coding scheme as Tables 8 and 9.

When examining the overall distribution of the papers surveyed across the questions in Tables 8 and 9, the following observations can be made. First, as evident from Figure 4, most studies have focused on questions of application, followed by those focusing on explanation, then by those focusing on organization. At the same time, the venues surveyed have shown differences in terms of their foci, and not all have prioritized application over explanation. For example, over half of the studies in DCC have focused on explanation, as compared with one quarter in E&PDE and nearly 15% in CAADRIA (Figure 5). Finally, classifying the paper population by sub-questions has shown that approximately three quarters of the studies explored a single question ($N = 194$), one fifth of the studies explored two questions in parallel ($N = 54$), and a few studies explored three ($N = 3$) or four ($N = 2$) sub-questions in parallel. The distribution of papers across sub-questions is visualized in Figure 6. This figure shows a dominance of studies focusing on developing new approaches and tools for enhancing design practice (B1–2, 99 occurrences), followed by works interested in enhancing our ability to use existing methods and tools (B1–1, 68 occurrences), then by studies aiming to use our theoretical lenses and tools to obtain empirical knowledge of design practice (A1–3, 53 occurrences), etc.

The revised taxonomy is simpler both at its highest level of organization (three questions instead of five) and at its lowest level of organization (13 sub-questions instead of 20). The following three major categories subsume all the works surveyed:

- Papers directed at **explaining** design-related phenomena (category A)
- Papers directed at **applying** our knowledge for enhancing design-related activity (category B)
- Papers directed at **organizing** our research output from the above categories (category C)

In this, the explanation of design practice as well as that of design education are acknowledged subcategories of a larger category that deals with the explanation of design-related activities (category A). The acts of enhancing our design methods and developing tools for practice/pedagogy are acknowledged as activities of knowledge mobilization and are thus nested under a single parent (category B). Category C, which corresponds to the first category in the original taxonomy, was organized to mirror the general structure of the field and now contains three questions, each corresponding to one category (A, B and C). Note that, referring to Table 9, questions A2–1 and A2–2

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Table 9. Proposed taxonomy for classifying works by research questions

	ID'	Sub-questions (how can we…)	ID"	Sub-questions (how can we…)	Knowledge produced	Example paper
Explain (A)	A1	…***understand design practice*** *from the standpoint of design computing research?*	A1–1	…***develop our lens*** *for* ***describing designing*** *as a form of computation?*	Revised/new frameworks for describing design practice	Urquhart *et al.* (2024)
			A1–2	…***build*** *computational* ***tools*** *for* ***inquiry into design****?*	Description of digital tools for processing, analyzing and visualizing designing	Kelly *et al.* (2024)
			A1–3	…***use our lenses and tools*** *to* ***study designing*** *from a computational perspective?*	Empirical knowledge concerning designing	Kim & Gero (2024)
	A2	…***understand design pedagogy*** *from the standpoint of design computing research?*	A2–1	…***develop our lens*** *for* ***describing design pedagogy*** *from a computational perspective?*	Revised/new frameworks or models for describing design pedagogy	–
			A2–2	…***build computational tools*** *for inquiry into* ***design pedagogy****?*	Description of digital tools for design pedagogy	–
			A2–3	…***use our lenses and tools*** *to* ***study design pedagogy*** *from a computational perspective?*	Empirical knowledge concerning design pedagogy	D'souza & Dastmalchi (2024)
Apply (B)	B1	…***apply*** *our knowledge in design computing research for* ***enhancing design practice?***	B1–1	…***use*** *our current computational* ***approaches/ tools*** *in* ***design practice****?*	Description of ways to utilize existing computational approaches and tools in design practice	Jowers, Clarke & Moat (2024)
			B1–2	…***create new*** *approaches/ tools for* ***design practice****?*	Description of ways to build new tools for design practice	Zhong *et al.* (2024)
	B2	…***apply*** *our knowledge in design computing research for* ***enhancing design pedagogy?***	B2–1	…***use*** *our current computational* ***approaches/ tools*** *in* ***design pedagogy****?*	Description of ways to utilize existing computational approaches and tools in design pedagogy	Silva *et al.* (2024)
			B2–2	…***create new*** *approaches/ tools for* ***design pedagogy****?*	Description of ways to build new tools for design pedagogy	Hadiatmadja (2024)

Continued

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Table 9. Continued

	ID'	Sub-questions (how can we…)	ID"	Sub-questions (how can we…)	Knowledge produced	Example paper
Organize (C)	C	*…**organize our knowledge** in design computing research?*	C1	*…**organize** knowledge concerning the **explanation of design-related activities?***	Syntheses of studies that explain design-related activity	Wang *et al.* (2024a)
			C2	*…**organize knowledge** concerning the **enhancement of design-related activities?***	Syntheses of studies that apply our knowledge for enhancing design-related activity	Khan, Erhan & Abuzuraiq (2024)
			C3	*…**organize knowledge** concerning **the field as a whole?***	Syntheses of studies across the field	Kahlon & Fujii (2024)

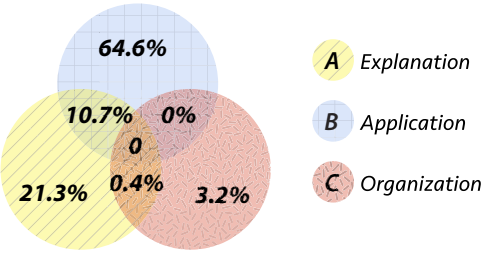


Figure 4. Overview of the distribution of papers across the three categories of activity.

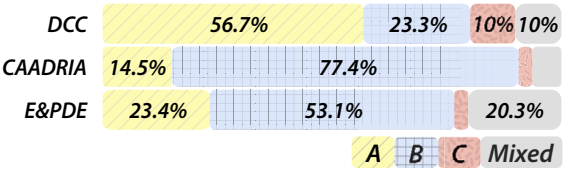


Figure 5. Distribution of papers across the categories of activity by venue (values ≥ 10% are shown).

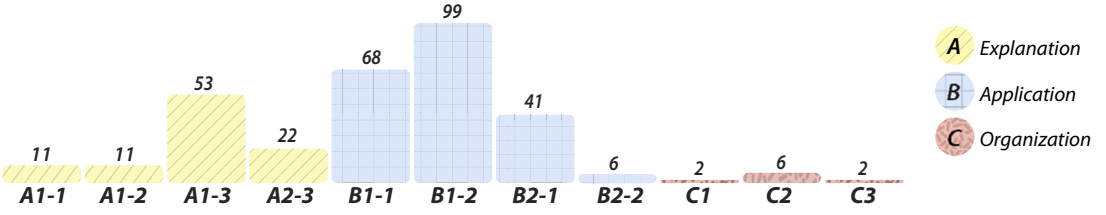


Figure 6. Occurrences of low-level sub-questions (values denote the total records exploring each sub-question).

were added for considerations of symmetry, despite the absence of corresponding papers in our sample. Rather than invalidating the potential importance of these questions, this absence may point to a research gap to be filled by future work.

Finally, all questions in the proposed taxonomy are of a single form ('*how can we…?*') that is design-oriented (i.e., one that focuses on how things may be in the future). This phrasing was chosen since research is a purposeful activity of knowledge production that aims to produce a preferable situation (Simon 2008) in which we have acquired new knowledge. In other words, inquiry into design is, to some extent, analogous with design (Fujii, Nakashima & Suwa 2013). Our phrasing, however, is intended to cover a large range of related questions of different forms. For example, the question of '*given two tools, which one would designers prefer?*' may be included in B1–1 (if the motivation of researchers is to formulate new methodologies which involve tools) or in B1–2 (if the motivation of the researchers is to create new tools), etc.

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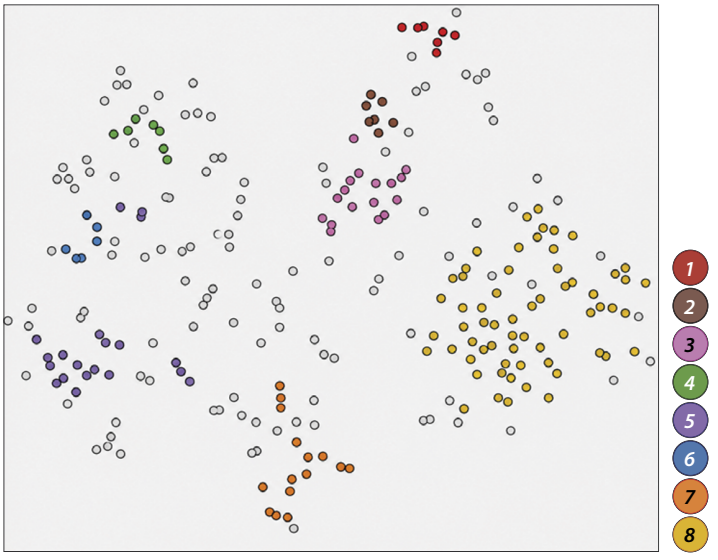


Figure 7. Paper clusters detected using HDBSCAN.

5.5 Computational exploration of paper clusters

The clusters that were computationally extracted from the data are given in Figure 7. Colored groups of points indicate strong data-driven clusters of papers. The remaining items (in gray) did not display a sufficiently strong correlation. In total, eight clusters were identified. Each cluster is described below, from the smallest one to the largest one. The descriptions include the number of papers in the cluster and common features that can be identified among the papers within it, as well as the relationship with the research questions pursued according to our survey.

First, in **cluster 6** ($N = 6$) we find papers that explore urban design from several viewpoints, such as automating the classification of spatial data (Jia, Zhang & Narahara 2024), or relating morphological characteristics with environmental performance (Bai & Zhang 2024). In this cluster, 4/6 items employ or discuss machine learning as the general computational approach employed.

Second, the shared property among the papers in **cluster 1** ($N = 7$) is the usage of technological means for obtaining bodily information from human designers/users. In 6/7 cases, EEG was used, albeit for different purposes. For example, while Jia *et al.* (2024) used it to learn about users' experience of architectural space, Gerothodoros *et al.* (2024) have used it for creating an interactive space that responds to users' emotions in real-time. With respect to the questions pursued, 6/7 papers were classified under category B. Among these, four occurrences of one sub-question were noted ('*How can we use our current computational approaches/tools in design practice?*') as well as four occurrences of another ('*How can we create new approaches/tools for design practice?*'). Papers in **cluster 2** ($N = 7$), which is related to cluster 1, all used EEG technology. However, while the work in cluster 1 was dominantly focused on questions in category B (6/7 items), the work in

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cluster 2 was primarily focused on questions in category A (5/7 items). Further note that all papers in cluster 1 belonged to the CAADRIA conference, while those in cluster 2 belonged exclusively to the DCC conference.

Third, the papers in **cluster 4** ($N = 7$) included two primary usages of computational tools for spatial design—for exploring human behavior (movement, circulation) and its relation to an existing space (Gao, Zhang & Huang 2024; Huang et al. 2024) or for designing/redesigning a space while considering human behavior (Dai, Huang & White 2024). In a single case, a computational system for spatial design was developed, yet human behavior was not explicitly considered (Wen, Ye & Yu 2024). Three papers in this cluster matched with the same question in category A (‘*How can we use our lenses and tools to study designing from a computational perspective?*’) while four others matched with the same question in category B (‘*How can we create new approaches/tools for design practice?*’).

Fourth, all items in **cluster 7** ($N = 15$) matched with category B (‘*How can we apply our knowledge in design computing research for enhancing design practice?*’), and specifically with one of its lowest-level questions (‘*How can we create new approaches/tools for design practice*?’). Overall, the common theme that unites the papers in this cluster is their concern with physical prototyping and fabrication. All the papers in this cluster belonged to a single conference (CAADRIA). Note that relevant works that were published in other venues and clearly matched the cluster’s theme (e.g. Benros *et al.* 2024) were not included.

Fifth, in **cluster 3** ($N = 17$), over half of the papers pursued questions in category A (11/17), while eight out of these pursued the same sub-question (‘*How can we use our lenses and tools to study designing from a computational perspective?’)*. Further, 11/17 papers reported on studies related to human design processes, yet from different perspectives. For example, Kelly *et al.* (2024) developed a way to visualize design cognition data, while Baudoux & Goucher-Lambert (2024) studied the interaction of human designers with a generative tool to help utilize it in designing. Additionally, seven papers in this cluster pursued more than one question in parallel. All papers in this cluster belonged to a single conference (DCC).

Sixth, all papers in **cluster 5** ($N = 20$) matched with the same question in category B (‘*How can we create new approaches/tools for design practice?*’). Among these, only one paper pursued another question in parallel (also included within category B). All papers in this category included the implementation of a computational system except one. Papers in this cluster belonged exclusively to a single conference (CAADRIA).

Finally, **cluster 8** ($N = 61$) was relatively diverse, with papers pursuing all the major questions in our classification system (A, B and C). Despite this diversity, all items in this cluster have discussed digital tools, and more than two-thirds (48/61) have explicitly dealt with topics related to AI. Also note that all papers in this cluster belonged to a single conference (E&PDE).

Overall, results show partial alignment between the automatically produced clusters and the research questions pursued. The best alignment was demonstrated between questions in category B and the computational output (which was occasionally perfect), followed by category A (which was always partial). No computationally produced cluster clearly matched with questions in category C.

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6. Discussion

6.1. Implications

6.1.1. Organizing design computing research

The revised taxonomy is simpler at its highest and lowest levels, yet accounts for the whole paper population under examination (N = 253). As the papers were extracted from three different conferences, which are characterized by unique perspectives with respect to design computing research, the taxonomy demonstrates potential for applicability to a diverse range of works across the field. The implications of the proposed taxonomy with respect to our understanding of design computing research are now discussed.

Design computing research is a subset of design science. To distinguish design science from other scientific activity, Simon (2008) suggested that the natural sciences focus on understanding how things are at the moment, while the sciences of the artificial (i.e., design science) reflect our desire to shape them in the future (also see Coyne *et al.* 1990, p. 11). However, this view of design science cannot account for the complete range of activity in design computing research—research in the field aims to both understand how things are (category A) *and* how we can shape them in the form of our desires (category B). For clarity, research activity in the proposed *category A* is akin to "pure" research, in the sense that its primary focus is on factual determination (Kuhn 1994) with respect to the current state of designing, teaching design, etc., while research activity in category B is akin to applied science. Of course, the output of category A *can* be used for the purpose of developing methods and applications (thereby supporting category B), but it may also serve a purpose in itself—that of explaining a phenomenon that is not yet sufficiently understood. In fact, some scientists regard explanation as the primary goal of science and the ability to utilize explanations for other purposes (e.g., prediction) as secondary (Deutsch 1997). Regardless of the relative importance of explanation versus application, design computing researchers can aim for either (or simultaneously for both). Therefore, the classification system highlights the descriptive as well as normative facets of the activity in design computing research.

With respect to the relation of the proposed framework to past works that have helped to organize the field, Gero and Maher have identified the following goals as fundamental to the activity in the field (1997): **(G1)** the desire to develop theories/models/methods of design processes; **(G2)** the desire to develop design tools using G1; and **(G3)** the desire to use G1 for teaching. In our proposed classification system, the descriptive part of G1 (the desire to produce explanations) is mapped onto category A, which also includes our desire to explain the act of teaching design. At the same time, the normative part of G1 (the desire to develop better methods for designing, etc.) maps onto category B, which also includes our attempts to improve any design-related activity. G2 and G3 are both subsumed within category B, which includes other normative activities (such as developing tools for pedagogy). Therefore, the proposed classification system preserves the fundamental structure exposed by Gero and Maher while embedding it within a broader context of purposes and distinguishing descriptive activities from normative ones. As the new classification system was developed by revising an existing taxonomy (Kahlon & Fujii 2025), we have documented the revisions made to the original taxonomy and the mapping of older items onto new ones. The information

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is provided in Appendix B, which includes the rationale for high-level revisions (Table B1), as well as specific mappings of previous low-level questions onto the newly introduced ones (Table B2).

6.1.2. Insights from the computational detection of clusters

Our computational exploration of automated clustering based on textual similarity has partially aligned with our manual classification. The implications of this are now discussed.

First, it is striking that, in certain cases, the automated clustering aligned completely with the proposed taxonomy. For example, all of the papers in cluster 7 matched with category B1, which reflects one of the main concerns in design computing—that of using our knowledge to enhance our practices and tools. The same applies to the papers in cluster 5, which also matched with category B in our proposed taxonomy. A similar result was observed with respect to our proposed category A, which matched with ~70% of the papers in the automatically detected cluster 2. These facts imply the plausibility of our categories as useful devices for classifying the activity in the field and demonstrate the potential of computational systems to help detect purpose-based clusters using unlabeled data. Yet, this will require further verification using larger and more diverse samples. The fact that no cluster corresponded with questions in category C may be attributed to the small number of relevant papers in the sample surveyed (e.g., review papers, etc.).

Second, as the computational method employed did not specify a predetermined criterion for clustering other than textual similarity, automated detection also resulted in clusters that did not clearly display a shared purpose. For example, cluster 8 did not display uniformity in terms of the questions pursued. In fact, eight different questions were pursued by works in this cluster (a significant portion of the works in this cluster did, however, share a common theme—the focus on AI). A similar result was observed on a smaller scale in cluster 6. This raises an important question regarding the organization of the research in design computing—what are the different dimensions that can be useful for organizing research works? Exploring this question can help to develop a multidimensional map that considers clusters from multiple complementary perspectives, which may be useful for a wide range of readers.

Finally, the eight clusters identified were all "pure" clusters in the sense that each contained proceedings from a single conference, occasionally excluding relevant works from other conferences. This suggests that differences in style or terminology adopted by a given community have an impact on the automated clustering result. At the same time, computational sensitivity to nuances may be conducive to detecting differences between groups of papers that look similar but are in fact different in terms of the question pursued. For example, papers in clusters 1 and 2 both dealt with neurocognitive measurement but were nonetheless assigned to different clusters. Indeed, the papers in each of these focused on two different types of questions (application versus explanation, respectively).

6.2. Limitations and future work

The main limitations of the current work are highlighted, and future directions for constructing a robust taxonomy for design computing research are suggested.

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First, the manual classification process was based on the recent proceedings of three different conferences, which helped to diversify the set of papers examined. However, papers from certain design domains were underrepresented (e.g., fashion design). Therefore, it is important to further increase the diversity of papers when mapping the field, to examine the applicability of the classification system to the broader activity in design computing research, and to revise it accordingly. Since the overarching questions are assumed to be domain-independent, further investigation into other domains is expected to primarily contribute to elaborating (and potentially reorganizing) our lower-level questions, which is important for identifying tightly linked clusters of works. Relatedly, a multi-year sampling that draws upon past periods in which major shifts have occurred (e.g., before the advent of CAD) may enable us to uncover questions that were once pursued but have been marginalized over time. Efforts to manually classify research questions can also benefit from including multiple human classifiers, which can strengthen our confidence in the validity of the results obtained, given that inter-rater reliability is established (Larsen *et al.* 2025).

Second, while the automated clustering performed in this study has yielded initial insights into the potential usefulness of the categories identified, further evaluation of the computational results is needed (e.g., stability tests, sensitivity analysis, etc.). Future studies can attempt to rigorously produce computational clusters, preferably by comparing the performance and output of multiple classification models and by considering the parameters by which clusters are evaluated for quality (Yao & Zeng 2026).

Third, the result of the automated clustering procedure has emphasized the need to consider the dimensions by which papers are clustered. As an initial step in mapping the field, we have focused on the aspect of purpose, which is fundamental to any research activity. However, as any paper population may be dissected differently by various criteria, it is important to determine those criteria that are useful for researchers. Having identified these, we can then examine the potential of automated classification to capture them and help organize the literature in the field.

Fourth, as we continue extracting and organizing the fundamental questions in the field, it would be useful to link them with the approaches and methods through which they are explored. Since the latter may be updated in short time spans due to methodological and technological advancements, it may be necessary to create a dynamic digital map that can continuously adapt to the changing landscape of design computing research. To do so, it would be essential to draw on computational approaches for automated extraction of such information, which will also enable us to consider a larger paper population in drawing a map for the whole field.

Finally, in tandem with organizing the field as a self-contained unit, it seems useful to examine its relationship with other important subfields in the broader landscape of design science, such as design cognition (Hay, Cash & McKilligan 2020). Note that some links are implicit in the proposed classification system (e.g., category A contains the usage of computational tools for explaining cognitive activity in designing), yet we would do well to make these explicit to better delineate the areas of concern for each sub-field as well as their interfaces.

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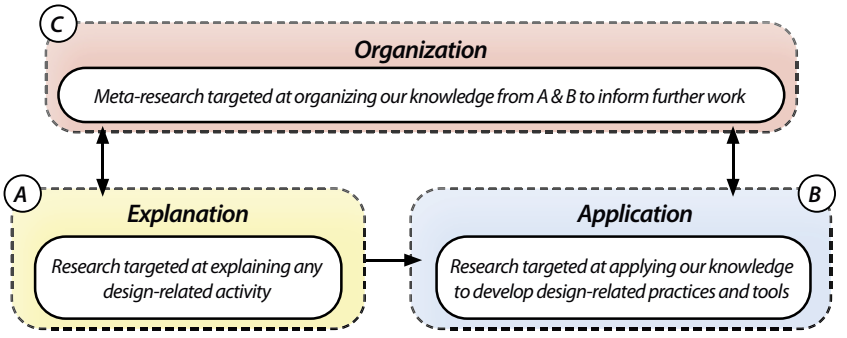


Figure 8. Classification systems overview.

7. Conclusion

An existing taxonomy for classifying works in the field of design computing research was applied to a set of 253 papers extracted from three well-known international conferences, leading to the proposal of a revised taxonomy. **The proposed taxonomy organizes the questions pursued by researchers into three major categories: (A) explanation, (B) application and (C) organization** (Figure 8). For all three categories, multiple sub-questions are enumerated, and example papers are provided in the form of an index.

The proposed taxonomy and index can help researchers position their work within a broader context and identify related questions. Additionally, it can help educators to draw fundamental distinctions between works in the field, thereby supporting design computing pedagogy. Furthermore, an examination of the relationship between our proposed categories and computationally detected clusters has demonstrated partial alignment between the two, thereby providing initial evidence for the potential usefulness of the taxonomy as a means for organizing works in design computing research. Future work can explore the utilization of computational approaches to identify alternative dimensions for organizing larger collections of works, as well as for further verification or revision of the categories proposed.

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Competing interests

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Appendix A

The complete classification results are reported below (Table A1). Record is assigned with IDs (1–253). Each record includes the venue, the title of the paper,

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Table A1. Complete classification of selected papers by the research questions pursued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
1	DCC	10.1007/978-3-031-71918-9_1	Automating useful representations of the design process from design protocols	[A], [B]	[A1–2], [A1–3], [B1–2], [B2–2]
2	DCC	10.1007/978-3-031-71918-9_2	Automating analogical reasoning: a wizard of Oz study on the benefits and pitfalls of a sketch-based AI image generator for design	[A], [B]	[A1–3], [B1–2]
3	DCC	10.1007/978-3-031-71918-9_3	Toward AI-assisted protocol analysis in design research: automating question labelling with GPT–4 according to eris' (2004) taxonomy	[A]	[A1–2], [A1–3]
4	DCC	10.1007/978-3-031-71918-9_4	Mapping design computing research	[C]	[C3]
5	DCC	10.1007/978-3-031-71918-9_5	The influence of semantic stimuli on design creativity: an EEG study from the perspective of design neurocognition	[A]	[A1–3]
6	DCC	10.1007/978-3-031-71918-9_6	Neurocognition of design creativity studied with EEG: A systematic literature review	[C]	[C1]
7	DCC	10.1007/978-3-031-71918-9_7	Thinking divergently: exploring the effects of ADHD on design creativity and cognitive load	[A]	[A1–3]
8	DCC	10.1007/978-3-031-71918-9_11	A quantitative examination of the visual perception of minimalism in architectural design according to the design experience	[A]	[A1–3]
9	DCC	10.1007/978-3-031-71918-9_12	Examining conflict patterns in hackathon teams: a case study	[A]	[A1–3]
10	DCC	10.1007/978-3-031-71918-9_13	Square-based honeycombs: a study of shape and performance	[B]	[B1–1]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
11	DCC	10.1007/978-3-031-71918-9_14	A generative multilingual shape grammar for mini and micro-housing design and its robotic construction	[B]	[B1–1], [B1–2]
12	DCC	10.1007/978-3-031-71918-9_15	Dougong revisited: a parametric specification of Chinese bracket design in shape machine	[A], [B]	[A1–2], [B1–2]
13	DCC	10.1007/978-3-031-71918-9_16	Redefining line maximization	[B]	[B1–1]
14	DCC	10.1007/978-3-031-71922-6_1	How do we know if a design space representation is useful? insights from the DS-viz method	[A], [C]	[A1–2], [A1–3], [C1], [C2]
15	DCC	10.1007/978-3-031-71922-6_2	Visual attention to biophilic elements in virtual classroom design: A VR eye-tracking study	[A]	[A1–3]
16	DCC	10.1007/978-3-031-71922-6_3	Optimization in parametric design thinking: are new models needed?	[A]	[A1–3]
17	DCC	10.1007/978-3-031-71922-6_4	Symmetry heuristics for stable reinforcement learning design agents	[B]	[B1–2]
18	DCC	10.1007/978-3-031-71922-6_5	Using personas to increase the diversity of design concepts generated by large language models	[B]	[B1–1]
19	DCC	10.1007/978-3-031-71922-6_6	A multi-case study of traditional, parametric, and generative design thinking of engineering students	[A]	[A2–3]
20	DCC	10.1007/978-3-031-71922-6_7	MazeMind: Exploring the effects of hand gestures and eye gazing on cognitive load and task efficiency in an augmented reality environment	[A]	[A1–2], [A1–3]
21	DCC	10.1007/978-3-031-71922-6_8	What is generative in generative artificial intelligence? a design-based perspective	[C]	[C2]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
22	DCC	10.1007/978-3-031-71922-6_9	An exploration of brain lateralization during engineering design ideation using fNIRS	[A]	[A1–3]
23	DCC	10.1007/978-3-031-71922-6_10	A new approach for examining the changes of brain behaviors between problem-finding and problem-solving in design teamwork	[A]	[A1–1], [A1–3]
24	DCC	10.1007/978-3-031-71922-6_11	Higher-order cognitive states recognition in open-ended design creation tasks using EEG microstate analysis and convolutional neural networks	[A]	[A1–3]
25	DCC	10.1007/978-3-031-71922-6_12	Neuro-cognitive feedback as a tool for improving cognitive endurance in engineering design	[B]	[A1–3], [B1–1],[B1–2]
26	DCC	10.1007/978-3-031-71922-6_13	Comparing engineering designers' brain activity in visuospatial reasoning tasks	[A]	[A1–3]
27	DCC	10.1007/978-3-031-71922-6_14	Assessing the alignment between word representations in the brain and large language models	[A]	[A1–3]
28	DCC	10.1007/978-3-031-71922-6_15	Architectural creativity stranded at mid journey? evaluating creative potential of prompts and images in generative AI	[A], [B]	[A2–3], [B1–1]
29	DCC	10.1007/978-3-031-71922-6_16	Semantic properties of word prompts shape design outcomes: understanding the influence of semantic richness and similarity	[A]	[A1–3]
30	DCC	10.1007/978-3-031-71922-6_17	Overcoming design challenges in coupled system device problems using agent-based models	[B]	[B1–1], [B1–2]
31	CAADRIA	10.52842/conf.caadria.2024.3.499	S(X)oundscape design based on virtual affordances	[B]	[B1–1]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
32	CAADRIA	10.52842/conf.caadria.2024.3.381	Designing a dynamically configurable digital twin for human-robot collaboration tasks: a case of working environment configuration for the robotic lab	[B]	[B1–1], [B1–2]
33	CAADRIA	10.52842/conf.caadria.2024.1.059	AI-enhanced performative building design optimization and exploration: a design framework combining computational design optimization and generative AI	[B]	[B1–2]
34	CAADRIA	10.52842/conf.caadria.2024.3.029	Architects' responses to practicing generative design for form finding in the schematic design stage	[A]	[A1–3]
35	CAADRIA	10.52842/conf.caadria.2024.3.459	Multisensory design in VR: implementing digital smell technologies for architecture	[A], [B]	[A1–2], [B1–2]
36	CAADRIA	10.52842/conf.caadria.2024.2.365	Estimating operational greenhouse gas emissions in the built environment using an urban digital twin: sustainable city management tool for decarbonisation of cities	[B]	[B1–2]
37	CAADRIA	10.52842/conf.caadria.2024.3.181	Curved glulam architecture design optimisation for low-tech construction: the fabrication and construction of KATENARA	[B]	[B1–1], [B1–2]
38	CAADRIA	10.52842/conf.caadria.2024.2.149	Survey of built environment in the era of UAV: from aerial photogrammetry to point cloud classification	[A]	[A1–2]
39	CAADRIA	10.52842/conf.caadria.2024.1.313	Exploring rule-based discrete timber design with mortise-tenon joints	[B]	[B1–1], [B1–2]
40	CAADRIA	10.52842/conf.caadria.2024.3.489	Real-time user experience and emotional state tracking in indoor architectural spaces using ChatGPT API and EEG	[B]	[B1–2]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
41	CAADRIA	10.52842/conf.caadria.2024.1.343	From sketch to design: a cross-scale workflow for procedural generative urban design	[B]	[B1–2]
42	CAADRIA	10.52842/conf.caadria.2024.1.271	UrbanSight: application of digital twin to augmented reality	[B]	[B1–2]
43	CAADRIA	10.52842/conf.caadria.2024.1.119	DSNL in architecture – a deep learning approach to deciphering architectural sketches and facilitating human-AI interaction	[B]	[B1–2]
44	CAADRIA	10.52842/conf.caadria.2024.1.303	Clicking is all you need: implementing wave function collapse in early-stage design for manufacturing and assembly projects	[B]	[B1–1]
45	CAADRIA	10.52842/conf.caadria.2024.1.485	Explainable AI and multi-objective optimization for energy retrofits in existing residential neighborhoods	[B]	[B1–2]
46	CAADRIA	10.52842/conf.caadria.2024.2.079	Density gradient concrete fabrication with injection 3D gypsum printing	[B]	[B1–1], [B1–2]
47	CAADRIA	10.52842/conf.caadria.2024.3.211	RE-MYCE: mycelium biocomposite based façade system optimization for land-slide-resistant structure in Yunnan mountainous region	[B]	[B1–2]
48	CAADRIA	10.52842/conf.caadria.2024.2.169	Text-to-city: controllable 3D urban block generation with latent diffusion model	[B]	[B1–2]
49	CAADRIA	10.52842/conf.caadria.2024.3.401	EMO-space: a computational model for interaction between emotions and space	[B]	[B1–1]
50	CAADRIA	10.52842/conf.caadria.2024.1.261	Review on the use of conversational AI NPC avatars in teaching and learning BIM: a preliminary observation of its introduction in a built environment related course in Singapore	[B]	[B2–1], [B2–2]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
51	CAADRIA	10.52842/conf.caadria.2024.2.119	Perception and reality: urban green space analysis using language model-based social media insights. a case study within Shanghai's inner ring	[A], [B]	[A1–3], [B1–2]
52	CAADRIA	10.52842/conf.caadria.2024.2.293	Reimaging muqarnas: exploring generative design for innovative patterns in Iranian Islamic architecture	[B]	[B1–2]
53	CAADRIA	10.52842/conf.caadria.2024.2.231	Participatory space auto-encapsulation: bridging human relationships to building typology with machine intelligence	[B]	[B1–2]
54	CAADRIA	10.52842/conf.caadria.2024.3.121	3D Printing Self-Shading Wall Structure With Earth. Enhancing Thermal Properties in Earthen Architecture Through Computational tool path design, inspired by nature & vernacular architecture	[B]	[B1–1]
55	CAADRIA	10.52842/conf.caadria.2024.1.445	Coastal infrastructure design: researching sea-waves and textured surfaces interaction using physical and virtual wave flumes	[B]	[B1–1]
56	CAADRIA	10.52842/conf.caadria.2024.3.131	A biomimetic robotic system with tensegrity-based compliant mechanism	[B]	[B1–1], [B1–2]
57	CAADRIA	10.52842/conf.caadria.2024.1.475	Design optimization through CFD-ABMS integration for controlling virus spread	[B]	[B1–2]
58	CAADRIA	10.52842/conf.caadria.2024.1.251	Predicting pedestrian trajectories in architectural spaces: a graph neural network approach	[B]	[B1–2]
59	CAADRIA	10.52842/conf.caadria.2024.2.139	Sensing streets: exploring the association between cityscape qualities and street perceptions using street view imagery and natural language processing	[A]	[A1–2], [A1–3]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
60	CAADRIA	10.52842/conf.caadria.2024.2.089	Distribution of carbon storage and potential strategies to enhance carbon sequestration capacity in Singapore: a study based on machine learning simulation and geospatial analysis	[B]	[B1–2]
61	CAADRIA	10.52842/conf.caadria.2024.2.069	Convolutional neural network-based predictions of potential flash flood hotspots in Singapore: insights and strategic interventions	[B]	[B1–2]
62	CAADRIA	10.52842/conf.caadria.2024.1.405	A parametric method in room acoustics simulation with performance verification: real-time ray tracing techniques in parametric modeling	[B]	[B1–2]
63	CAADRIA	10.52842/conf.caadria.2024.2.475	The effects of curbside cafés on bike travel behaviours: spatiotemporal evidence from Toronto	[A]	[A1–3]
64	CAADRIA	10.52842/conf.caadria.2024.3.411	Exploring spatial arrangement of locker area in ski resort hall for enhancing interpersonal distancing using unity engine	[A]	[A1–3]
65	CAADRIA	10.52842/conf.caadria.2024.2.109	Leveraging social media and natural language processing for understanding cultural perception in urban renewal: insights from Nantou walled city	[A]	[A1–1]
66	CAADRIA	10.52842/conf.caadria.2024.3.231	Sustainable structural prototype using bamboo-based mycelium composite substrate	[A]	[A1–3]
67	CAADRIA	10.52842/conf.caadria.2024.3.321	Extruding dredged-based material for concrete formwork through rapid liquid printing	[B]	[B1–1], [B1–2]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
68	CAADRIA	10.52842/conf.caadria.2024.1.169	Drag2build: interactive point-based manipulation of 3D architectural point clouds generated from a single image	[B]	[B1–1]
69	CAADRIA	10.52842/conf.caadria.2024.2.009	A discriminator with deep learning (ResNet-LST) for evaluating the impact of urban morphological indicators on urban land surface temperatures	[B]	[B1–2]
70	CAADRIA	10.52842/conf.caadria.2024.1.159	Learning and generating spatial concepts of modernist architecture via graph machine learning	[B]	[B1–2]
71	CAADRIA	10.52842/conf.caadria.2024.3.099	Learning through making using augmented reality: a case study in accelerated learning	[A], [B]	[A2–3], [B2–1]
72	CAADRIA	10.52842/conf.caadria.2024.1.049	Adapting the software design pattern model for ai-enabled design computing	[B]	[B1–2]
73	CAADRIA	10.52842/conf.caadria.2024.3.469	Nighttime outdoor lighting environment design system using web-based mixed reality to reduce light pollution	[B]	[B1–2]
74	CAADRIA	10.52842/conf.caadria.2024.2.059	Combining social media images and bitemporal satellite images for automated detection of damaged areas after flooding	[B]	[B1–2]
75	CAADRIA	10.52842/conf.caadria.2024.2.211	Enabling design partnerships through parametric design visualisation: a case study of visual communication techniques implemented on an infrastructure design project where partnership with indigenous communities was integral to success	[B]	[B1–2]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
76	CAADRIA	10.52842/conf.caadria.2024.1.211	BIM-enabled regulatory design rule checking for building circulation	[B]	[B1–2]
77	CAADRIA	10.52842/conf.caadria.2024.2.465	Shared pathway analysis for pedestrians, cyclists and ePMD users	[B]	[B1–2]
78	CAADRIA	10.52842/conf.caadria.2024.1.231	Extracting spatial structure from building information models	[B]	[B1–1]
79	CAADRIA	10.52842/conf.caadria.2024.2.405	Informed design of pedestrian pathways	[A]	[A1–3]
80	CAADRIA	10.52842/conf.caadria.2024.1.099	ChatDesign: bootstrapping generative floor plan design with pre-trained large language models	[B]	[B1–2]
81	CAADRIA	10.52842/conf.caadria.2024.3.151	A modulus-based encoding method for continuous gradient pattern in architectural knitted fabrics	[B]	[B1–1], [B1–2]
82	CAADRIA	10.52842/conf.caadria.2024.1.535	Multispecies building envelopes: adopting plant habitat suitability modelling for ecological design decision-making	[B]	[B1–2]
83	CAADRIA	10.52842/conf.caadria.2024.2.485	Unraveling the dynamics of urban catering: analysing the factors in shaping neighbourhood restaurants sceneries	[A]	[A1–3]
84	CAADRIA	10.52842/conf.caadria.2024.3.201	Fungus mesh: non-woven self-supporting assemblies	[B]	[B1–1]
85	CAADRIA	10.52842/conf.caadria.2024.2.395	Inconsistent affective reaction: sentiment of perception and opinion in urban environments	[A]	[A1–2], [A1–3]
86	CAADRIA	10.52842/conf.caadria.2024.3.059	Eduverse: exploring gamification and the metaverse in architectural pedagogy	[B]	[B2–1], [B2–2]
87	CAADRIA	10.52842/conf.caadria.2024.1.383	Turning empirical knowledge into digital assets: a workflow assisting intern architects in high-rise conceptual design	[B]	[B1–2]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
88	CAADRIA	10.52842/conf.caadria.2024.1.069	ARCHICLIP: enhanced contrastive language–image pre-training model with architectural prior knowledge	[B]	[B1–2]
89	CAADRIA	10.52842/conf.caadria.2024.1.009	A method for real-time prediction of indoor natural ventilation in residential buildings	[B]	[B1–2]
90	CAADRIA	10.52842/conf.caadria.2024.2.099	Do visually perceived design qualities influence dockless bikeshare cycling routes? a case study of ithaca using gps trajectories	[A]	[A1–3]
91	CAADRIA	10.52842/conf.caadria.2024.2.201	Digital participation in urban design and planning: addressing data translation challenges in urban policy- and decision-making through visualization techniques	[B]	[B1–2]
92	CAADRIA	10.52842/conf.caadria.2024.3.171	Co-intelligent design toward modular structures	[B]	[B1–1], [B1–2]
93	CAADRIA	10.52842/conf.caadria.2024.1.241	More words from facility operation managers: text-based building information for inclusive accessibility	[B]	[B1–2]
94	CAADRIA	10.52842/conf.caadria.2024.3.371	A pneumatic system design toolkit for learning and creative applications	[B]	[B1–2]
95	CAADRIA	10.52842/conf.caadria.2024.2.221	Kit-of-parts design for architecture co-creation games	[A], [B]	[A1–3], [B1–2]
96	CAADRIA	10.52842/conf.caadria.2024.2.505	Urban site adaptive layout generation: user-configurable algorithms based on MQP	[B]	[B1–1]
97	CAADRIA	10.52842/conf.caadria.2024.3.079	Evolving architectural paradigms: a study of levels of automation in architecture	[C]	[C2]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
98	CAADRIA	10.52842/conf.caadria.2024.3.349	Woodenwood: integrating wood waste in design through robotic printing and traditional craft	[B]	[B1–1]
99	CAADRIA	10.52842/conf.caadria.2024.3.049	Decisions we should put in the algorithm: mapping architects' attitudes toward computational and AI-powered tools for practice	[B]	[B1–2]
100	CAADRIA	10.52842/conf.caadria.2024.3.191	Diatoma: a biomimetic fabrication-aware lightweight pavilion	[B]	[B1–1]
101	CAADRIA	10.52842/conf.caadria.2024.1.545	Uncovering the circular potential: estimating material flows for building systems components reuse in the Swiss built environment	[B]	[B1–2]
102	CAADRIA	10.52842/conf.caadria.2024.1.435	Bridging exterior and interior climate: interdisciplinary design of a dual-functional adaptive kinetic façade prototype	[B]	[B1–1]
103	CAADRIA	10.52842/conf.caadria.2024.2.241	Re-commoning urban spaces from the bottom-up: empowering urban communities: a digital toolbox for bottom-up intervention in Kottbusser Tor, Berlin	[B]	[B1–2]
104	CAADRIA	10.52842/conf.caadria.2024.1.139	GRAPH2PIX: a generative model for converting room adjacency relationships into layout images	[B]	[B1–2]
105	CAADRIA	10.52842/conf.conf.caadria.2024.3.421	Generating 4D plant models for virtual reality environments using the instant neural graphics primitives and stable diffusion model	[B]	[B1–2]
106	CAADRIA	10.52842/conf.caadria.2024.3.519	VAULT.SPACE: an evaluation of the metaverse iconic landmarks of Singapore island on a hybrid map	[A]	[A1–3]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
107	CAADRIA	10.52842/conf.caadria.2024.3.329	Mass-customization of integrated green wall building blocks through clay printing formwork	[B]	[B1–1]
108	CAADRIA	10.52842/conf.caadria.2024.2.335	An ontology-based reasoning framework: toward multi-level and data-efficient building material stock modelling	[B]	[B1–2]
109	CAADRIA	10.52842/conf.caadria.2024.3.431	Improving metro station navigation: findings from an online virtual reality wayfinding experiment	[A], [B]	[A1–3], [B1–1]
110	CAADRIA	10.52842/conf.caadria.2024.2.039	Characterizing residential building patterns in high-density cities using graph convolutional neural networks	[B]	[B1–2]
111	CAADRIA	10.52842/conf.caadria.2024.3.263	3D concrete printing frame structure in granular medium	[B]	[B1–1], [B1–2]
112	CAADRIA	10.52842/conf.caadria.2024.2.385	Exploring visual factors influencing women's perceived insecurity in metro stations and adjacent built environments: a case study of Milan, Italy	[A]	[A1–3]
113	CAADRIA	10.52842/conf.caadria.2024.1.029	A rapid prediction model for view-based glare performance with multimodal generative adversarial networks	[B]	[B1–2]
114	CAADRIA	10.52842/conf.caadria.2024.1.363	Rule-based generation of interwoven assemblies in architectural design: a computational approach integrating attribute grammar	[B]	[B1–1], [B1–2]
115	CAADRIA	10.52842/conf.caadria.2024.3.291	Assembly of spaceframes in hybrid teams: adaptive digital fabrication workflows for human-robot collaboration	[B]	[B1–1]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
116	CAADRIA	10.52842/conf.caadria.2024.3.039	Back to black boxes? an urgent call for discussing the impacts of the emergent AI-driven tools in the architecture design education	[B]	[B2–1]
117	CAADRIA	10.52842/conf.caadria.2024.1.333	Formal variation exploration for performance-based building massing design optimization	[B]	[B1–2]
118	CAADRIA	10.52842/conf.caadria.2024.1.465	Design factor-oriented life-cycle energy optimisation for early-stage building design	[B]	[B1–2]
119	CAADRIA	10.52842/conf.caadria.2024.3.221	Research on the generation methods of topological interlocking structure on surfaces based on grid	[B]	[B1–2]
120	CAADRIA	10.52842/conf.caadria.2024.1.089	Can generative AI models count? finetuning stable diffusion for architecture image generation with designated floor numbers using a small dataset	[B]	[B1–2]
121	CAADRIA	10.52842/conf.caadria.2024.1.179	Pseudo-cross-modal translation: bridging architectural plan and perspective through a pix2pix network	[B]	[B1–2]
122	CAADRIA	10.52842/conf.caadria.2024.1.323	Extracting actionable information from the site context using a phenotype-based strategy	[B]	[B1–2]
123	CAADRIA	10.52842/conf.caadria.2024.3.449	Micro-spatial elements and their impact on socio-spatial behaviour: a study in virtual reality	[A]	[A1–3]
124	CAADRIA	10.52842/conf.caadria.2024.1.353	Re-imagining the urban development of western Sydney: the case study of Oran Park	[B]	[B1–1]
125	CAADRIA	10.52842/conf.caadria.2024.2.159	Territorial sabotage: from tracing Seoul's possibilities to recompositing its urban identity	[B]	[B1–2]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
126	CAADRIA	10.52842/conf.caadria.2024.2.415	Interactive mediatized urbanism: shaping high emotional value food consumption spaces with human data on social media	[B]	[B1–2]
127	CAADRIA	10.52842/conf.caadria.2024.3.391	Electroencephalogram (EEG) based emotional lighting design using deep-learning for a user-centric approach	[B]	[B1–1], [B1–2]
128	CAADRIA	10.52842/conf.caadria.2024.2.425	Layout evaluation and optimization strategy for retail space integration into existing subway stations: an agent-based modelling approach, a case study of Beijing subway line 4 Xinyuan station	[B]	[B1–2]
129	CAADRIA	10.52842/conf.caadria.2024.3.539	Web-based 3D heatmap visualization of spatial cognition using EEG and Eye tracking data	[B]	[B1–2]
130	CAADRIA	10.52842/conf.caadria.2024.3.109	On the information scape of spaces	[A]	[A1–1], [A1–3]
131	CAADRIA	10.52842/conf.caadria.2024.1.425	An approach to improve individual thermal comfort based on mobile measurement of biological reaction to proximate thermal environment	[B]	[B1–1]
132	CAADRIA	10.52842/conf.caadria.2024.1.415	A phygital form-finding method for body-scale soundscape installation with flexible materials	[B]	[B1–1]
133	CAADRIA	10.52842/conf.caadria.2024.1.395	A knowledge graph model for performance-based generative design and its applications in accelerated design	[A],[B]	[A1–1], [B1–2]
134	CAADRIA	10.52842/conf.caadria.2024.3.339	ReciproFrame timber gridshell: from CAM data interface modeling to operating industrial joinery machine for scaling up reusable timber structures	[B]	[B1–1]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
135	CAADRIA	10.52842/conf.caadria.2024.1.109	Deep spatial memory: quantifying architectural spatial experiences through agent-driven simulations and deep learning	[A]	[A1–2], [A1–3]
136	CAADRIA	10.52842/conf.caadria.2024.2.515	Visualising Sydney's urban green: a web interface for monitoring vegetation coverage between 1992 and 2022 using google earth engine	[B]	[B1–2]
137	CAADRIA	10.52842/conf.caadria.2024.1.149	Latent petroglyphs: pattern extraction from prehistoric rock art through generative workflows for a design project in Greece	[B]	[B1–2]
138	CAADRIA	10.52842/conf.caadria.2024.1.505	Integrating genetic algorithms and RBF neural networks in the early design stage of gymnasium for multi-objective optimization framework	[B]	[B1–2]
139	CAADRIA	10.52842/conf.caadria.2024.2.303	User-centered design (UCD) based web vr for the value of cultural heritage	[B]	[B1–1]
140	CAADRIA	10.52842/conf.caadria.2024.2.019	A framework for fine-tuning urban GANs using design decision data generated by architects through GANs applications	[B]	[B1–2]
141	CAADRIA	10.52842/conf.caadria.2024.3.441	Interdisciplinary collaboration in the design process of interactive exhibits focusing on new materials	[B]	[B1–1]
142	CAADRIA	10.52842/conf.caadria.2024.2.129	Prediction, simulation and evaluation of stay behavior in public space integrated with microclimate	[B]	[B1–1], [B1–2]
143	CAADRIA	10.52842/conf.caadria.2024.1.283	A Hybrid multi-objective model for multi-story warehouse design: a case study in Shenzhen	[B]	[B1–2]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
144	CAADRIA	10.52842/conf.caadria.2024.1.221	Bridging bim and AI: a graph-bim encoding approach for detailed 3D layout generation using variational graph autoencoder	[B]	[B1–1]
145	CAADRIA	10.52842/conf.caadria.2024.3.161	A study of viability and characteristic of 3D-printable mortar with yellow river sand	[A], [B]	[A1–3], [B1–1]
146	CAADRIA	10.52842/conf.caadria.2024.1.189	The intersection of technology and architecture: smartphone photography in carbon analysis	[B]	[B1–2]
147	CAADRIA	10.52842/conf.caadria.2024.1.039	Accelerating future scenario development for concept design with text-based GenAI (ChatGPT)	[B]	[B1–1]
148	CAADRIA	10.52842/conf.caadria.2024.1.019	A pattern coloring method using rank-based interactive evolutionary algorithm	[B]	[B1–2]
149	CAADRIA	10.52842/conf.caadria.2024.3.361	A comparative analysis of different locomotion in virtual reality and their consequence in spatial cognition	[A]	[A1–3]
150	CAADRIA	10.52842/conf.caadria.2024.2.313	Utilizing UV-mapping for the 3D-point cloud segmentation of architectural heritage	[B]	[B1–1]
151	CAADRIA	10.52842/conf.caadria.2024.3.479	Perceptual materialization for space interface: exploring the interactive generation design method and application of space interface via EEG reveled visual-perception	[B]	[B1–1], [B1–2]
152	CAADRIA	10.52842/conf.caadria.2024.3.281	An adaptive structure prototype design method based on discrete modular assembly system	[B]	[B1–2]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
153	CAADRIA	10.52842/conf.caadria.2024.2.435	Quantifying and mitigating neighborhood transportation CO2 emissions through data-driven urban design	[B]	[B1–2]
154	CAADRIA	10.52842/conf.caadria.2024.2.445	Revisiting William H. Whyte's diagram: an interactive video-tracking method for modelling spatiotemporal human behaviors within dynamic zoning geometries	[B]	[B1–2]
155	CAADRIA	10.52842/conf.caadria.2024.3.311	Design strategies for repair of 3D printed biocomposite materials	[B]	[B1–1]
156	CAADRIA	10.52842/conf.caadria.2024.2.345	Assessing heat exposure risks among different urban demographics to enhance public health during heat waves: a case study in Nanjing	[B]	[B1–1]
157	CAADRIA	10.52842/conf.caadria.2024.2.455	Scale mismatching: prevalent compactness indexes of urban form do not work in computational urban design	[A]	[A1–1]
158	CAADRIA	10.52842/conf.caadria.2024.2.325	A review of compactness indexes of form in computational urban design	[C]	[C2]
159	CAADRIA	10.52842/conf.caadria.2024.1.525	Mixed-use eco-computational design in hot climates: a two-step cross-climate parametric workflow	[A], [B]	[A1–3], [B1–1]
160	CAADRIA	10.52842/conf.caadria.2024.1.079	Architectural generative model evaluation methods: image quality assessment metrics and expert-based approach	[B]	[B1–2]
161	CAADRIA	10.52842/conf.caadria.2024.1.373	SIMForms: a web-based generative application fusing forms, metrics, and visuals for early-stage design	[B]	[B1–2]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
162	CAADRIA	10.52842/conf.caadria.2024.2.049	CocoBot: developing a consent communication tool based on co-evolutionary model	[A], [B]	[A1–3], [B1–2]
163	CAADRIA	10.52842/conf.caadria.2024.2.029	Analysis of differences in street visual walkability perception between DCNN and ViT model based on panoramic street view images	[A]	[A1–2]
164	CAADRIA	10.52842/conf.caadria.2024.2.375	Exploring nonlinear relationship between built environment and street vitality using machine learning: a case study of ding Shu, China	[A]	[A1–3]
165	CAADRIA	10.52842/conf.caadria.2024.2.253	Investigating condensation risks on heritage building surfaces using Blinn Phong BRDF model and attribute information of point cloud data	[B]	[B1–1]
166	CAADRIA	10.52842/conf.caadria.2024.2.495	Urban analytics and generative deep learning for context responsive design in digital twins: a Singapore study	[B]	[B1–2]
167	CAADRIA	10.52842/conf.caadria.2024.2.283	Enhancing cultural heritage digitalization and visitor engagement through LiDAR scanning and gamification	[B]	[B1–1]
168	CAADRIA	10.52842/conf.caadria.2024.1.293	Architectural topological form-finding integrating solid and fluid structural performances	[B]	[B1–1], [B1–2]
169	CAADRIA	10.52842/conf.caadria.2024.3.069	Empirical insights into architectural aesthetics: a neuroscientific perspective	[A]	[A1–1], [A1–3]
170	CAADRIA	10.52842/conf.caadria.2024.3.301	Bendscape: optimized manufacturing by incorporating tool development and machining in design	[B]	[B1–1]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
171	CAADRIA	10.52842/conf.caadria.2024.3.141	A case study on structural morphology of bamboo woven structure: formal and structural integration in weaving	[A]	[A1–3]
172	CAADRIA	10.52842/conf.caadria.2024.1.129	From topology to spatial information: a computational approach for generating residential floorplans	[B]	[B1–2]
173	CAADRIA	10.52842/conf.caadria.2024.2.355	assessing path choosing in mountainous cities via pedestrian network data and subway station observations: a case study of Jiefangbei, Chongqing	[A], [B]	[A1–3], [B1–1]
174	CAADRIA	10.52842/conf.caadria.2024.3.549	Spaceshifter: A virtual environment with emotional intelligence	[B]	[B1–1]
175	CAADRIA	10.52842/conf.caadria.2024.3.019	ArchiSearch: A text-image integrated case-based search engine in architecture using self-organizing maps	[B]	[B1–2]
176	CAADRIA	10.52842/conf.caadria.2024.2.273	Deep winning form: machine investigation of architectural quality	[B]	[B1–2]
177	CAADRIA	10.52842/conf.caadria.2024.3.509	The study on augmented reality positioning maps for historical and cultural site navigation	[B]	[B1–1]
178	CAADRIA	10.52842/conf.caadria.2024.3.089	From pencil to pixel: the evolution of design ideation tools	[A]	[A1–1], [A1–3]
179	CAADRIA	10.52842/conf.caadria.2024.1.201	BatchPlan: A large scale solution for floor plan extraction	[B]	[B1–1]
180	CAADRIA	10.52842/conf.caadria.2024.3.529	Virtual space generation method driven by integrated multi-sensory feedback data	[B]	[B1–1], [B1–2]
181	CAADRIA	10.52842/conf.caadria.2024.3.271	3D concrete printing in a circular economy: what we can learn from a 3DCP slab designed for dissassembly	[B]	[B1–1]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
182	CAADRIA	10.52842/conf.caadria.2024.3.009	Algorithmic design explained: decomposing parametric 3D problems into 2D visual illustrations	[B]	[B1–2]
183	CAADRIA	10.52842/conf.caadria.2024.1.515	Making a case for design analytics: complementing designers' toolbox for data-informed creative decision-making	[B]	[B1–1]
184	CAADRIA	10.52842/conf.caadria.2024.1.455	D-predict: integrating generative design and surrogate modelling with design analytics	[B]	[B1–2]
185	CAADRIA	10.52842/conf.caadria.2024.2.181	A critical review of data democratisation and its adoption in designing built-environments	[C]	[C3]
186	CAADRIA	10.52842/conf.caadria.2024.1.495	Glare prediction in check-in halls of airport terminals using integrated algorithms and transfer learning strategy: a case study of Guangzhou Baiyun international airport	[B]	[B1–2]
187	CAADRIA	10.52842/conf.caadria.2024.2.263	Characterization of the Chinese Traditional Villages Based on the Morphological Clustering and Knowledge Graph	[A]	[A1–1], [A1–3]
188	CAADRIA	10.52842/conf.caadria.2024.2.191	D-ARE: A Location-Based Augmented Reality Tool for Public Engagement in Design of Built Environment	[B]	[B1–2]
189	CAADRIA	10.52842/conf.caadria.2024.3.253	A Method for Designing a Breathing Modular Wall	[B]	[B1–1]
190	E&PDE	10.35199/epde.2024.1	Exploring the synergy of AI generative fill in photoshop and the creative design process utilising informal learning	[A]	[A2–3]
191	E&PDE	10.35199/epde.2024.2	Embodied design experiences first - before designing with(in) AI	[B]	[B1–1]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
192	E&PDE	10.35199/epde.2024.3	A comparison of artificial intelligence image generation tools in product design	[A], [B]	[A1–3], [B1–1]
193	E&PDE	10.35199/epde.2024.4	Impacts of generative AI on engineering and product design students' performance	[A]	[A2–3]
194	E&PDE	10.35199/epde.2024.5	Authentic video feedback for product design students	[B]	[B2–1]
195	E&PDE	10.35199/epde.2024.7	Exploring the impact of generative AI on concept generation, ideation, and design methodology: in product design education	[A]	[A2–3]
196	E&PDE	10.35199/epde.2024.13	Exploring the challenges to integrate VR modelling in product design education	[B]	[B2–1]
197	E&PDE	10.35199/epde.2024.16	Designing AI-enhanced teaching products for university OMO classrooms	[B]	[B2–2]
198	E&PDE	10.35199/epde.2024.17	The role for AI in a coil project involving fast fashion, personal floatation devices, and a LMIC community	[A]	[A2–3]
199	E&PDE	10.35199/epde.2024.18	A systematic review of the role of AI artificial intelligence in design education	[C]	[C2]
200	E&PDE	10.35199/epde.2024.19	Back to basics? technical drawing, sketching and visual communication in the AI era	[B]	[B2–1]
201	E&PDE	10.35199/epde.2024.20	Use of artificial intelligence in the product design process. impact on the details design stage	[A]	[A2–3]
202	E&PDE	10.35199/epde.2024.23	How can AI support the creation of novel ideas in product design	[A], [B]	[A2–3], [B2–1]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
203	E&PDE	10.35199/epde.2024.24	Partnering with the intelligence community to enhance AI interface design education	[B]	[B2–1]
204	E&PDE	10.35199/epde.2024.27	Perceptions of lecturers of artificial intelligence on industrial design students	[A], [B]	[A2–3], [B1–1]
205	E&PDE	10.35199/epde.2024.30	Dreamworlds: a case study presenting the potential of text-to-Image AI in product design education	[B]	[B2–1]
206	E&PDE	10.35199/epde.2024.31	Modelling interior yacht design concepts crossing multiple AI tools: teaching in an uncertain and flexible framework	[A], [B]	[A2–3], [B2–1]
207	E&PDE	10.35199/epde.2024.32	User engagement in physical-digital interaction design	[A], [B]	[A1–1], [B2–2]
208	E&PDE	10.35199/epde.2024.34	Comparing understandability of hand sketches versus AI-generated renders for product design	[A]	[A2–3]
209	E&PDE	10.35199/epde.2024.36	Transformative learning in product design workshops: a generative AI assistant approach	[B]	[B2–1]
210	E&PDE	10.35199/epde.2024.38	Design and implementation of a skill development program in AI driven generative engineering	[B]	[B2–1]
211	E&PDE	10.35199/epde.2024.39	Invite the elephant into the room: an analysis of design students' ChatGPT Use in a scientific article writing course	[A]	[A2–3]
212	E&PDE	10.35199/epde.2024.40	Concept to production with a gen ai design assistant: AIDA	[B]	[B1–2]
213	E&PDE	10.35199/epde.2024.42	Binding AI and XR in design education: challenges and opportunities with emerging technologies	[B]	[B2–1]

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ID	Venue	Stable identifier	Title	Questions	Sub-questions
214	E&PDE	10.35199/epde.2024.43	Assessing the eye gaze behaviors of illustrators sketching facial expressions from observation	[A]	[A1–3]
215	E&PDE	10.35199/epde.2024.44	Understanding how undergraduate students perceive biases in Ai-generated images, a research-through-design probe	[A], [B]	[A2–3], [B2–1]
216	E&PDE	10.35199/epde.2024.48	Integrating AR into a graphic design program for an enhanced design curriculum	[B]	[B2–1]
217	E&PDE	10.35199/epde.2024.50	Culturally grounded speculation: framework for ethnography informed ai-driven design for diverse futures	[A], [B]	[A2–3], [B1–1]
218	E&PDE	10.35199/epde.2024.52	Visualizing speculative materials: using text-to-image prompting to elaborate livingness as a designed material quality	[A], [B]	[A1–3], [B1–1]
219	E&PDE	10.35199/epde.2024.55	Reimagining design fundamentals: deschooling 1st year product design students	[B]	[B2–1]
220	E&PDE	10.35199/epde.2024.56	The trajectory of design sketching: an inquiry into educational pathways, higher education transitions & design sketching syllabus development for 1st year product design students	[B]	[B2–1]
221	E&PDE	10.35199/epde.2024.57	Understanding how undergraduate students perceive biases in AI-generated images, a research-through-design probe	[B]	[B2–1], [B2–2]
222	E&PDE	10.35199/epde.2024.58	Toward an education system aimed at enhancing the embodied, enactive and interactive experience through new realities	[B]	[B2–1]

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Table A1. Continued

ID	Venue	Stable identifier	Title	Questions	Sub-questions
223	E&PDE	10.35199/epde.2024.60	Optimizing learning in industrial engineering; improving skills through xr enhanced learning scenarios	[B]	[B2–1]
224	E&PDE	10.35199/epde.2024.62	Materiality and the machine. maximizing material experiences in the age of AI	[B]	[B2–1]
225	E&PDE	10.35199/epde.2024.63	Designing tomorrow: adapting curricula to the challenges of a rapidly changing world	[B]	[B2–1]
226	E&PDE	10.35199/epde.2024.64	Old Procedure - new approaches: QFD with ChatGPT - comprehensive product and process understanding in engineering design education	[B]	[B2–1]
227	E&PDE	10.35199/epde.2024.66	Fab thesis: a university master's programme	[B]	[B2–1]
228	E&PDE	10.35199/epde.2024.68	A transdisciplinary steam x d workshop on AI rescue robotics for pre-university students	[B]	[B2–1]
229	E&PDE	10.35199/epde.2024.70	Chat-GPT: A clever search engine or a creative design assistant for students and industry?	[A]	[A1–3], [A2–3], [B2–1]
230	E&PDE	10.35199/epde.2024.71	Supervision of design PhD students in an era of generative artificial intelligence	[A], [B]	[A2–3], [B2–1]
231	E&PDE	10.35199/epde.2024.73	Generative AI in design education: business as usual, a troublemaker, or a game changer?	[B]	[B2–1]
232	E&PDE	10.35199/epde.2024.74	A blended approach of online tools to enhance collaboration ability in design education	[B]	[B2–1]
233	E&PDE	10.35199/epde.2024.76	Prompt engineering on the engineering design process	[B]	[B1–1]

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ID	Venue	Stable identifier	Title	Questions	Sub-questions
234	E&PDE	10.35199/epde.2024.78	Exploring the usability of ai prompts for mechanical engineering design development	[A], [B]	[A2–3], [B2–1]
235	E&PDE	10.35199/epde.2024.80	How will the emergence of AI in the world of industrial design change the training needs of our students?	[A], [B]	[A1–3], [B2–1]
236	E&PDE	10.35199/epde.2024.82	Learning activities to design a parametric solutions space for products in industry 4.0	[B]	[B2–1]
237	E&PDE	10.35199/epde.2024.83	Rethinking assessment for generative design education	[B]	[B2–1]
238	E&PDE	10.35199/epde.2024.89	A Design and AI Course: in Conversation with Machines	[B]	[B2–1]
239	E&PDE	10.35199/epde.2024.90	Exploring Chat GPT's impact on student team ideation outcomes for new product development: a pilot study	[A]	[A2–3]
240	E&PDE	10.35199/epde.2024.92	Who owns artificial intelligence?	[A]	[A1–1]
241	E&PDE	10.35199/epde.2024.93	Digitalization – is haptic understanding outdated in the teaching of geometrical product specifications (GPS)?	[A], [B]	[A1–3], [A2–3], [B2–1]
242	E&PDE	10.35199/epde.2024.94	Co-design and artificial intelligence: a method to empower end-users in visual communication	[A]	[A1–3]
243	E&PDE	10.35199/epde.2024.95	Co-design with persons with disabilities as an innovative resource set free by AI	[A], [B]	[A1–3], [B1–1]
244	E&PDE	10.35199/epde.2024.96	Bridging the relational gap: systemic design and AI, SPARCing sustainable education in universities	[B]	[B1–1], [B2–1]
245	E&PDE	10.35199/epde.2024.98	Development of a Fully Functioning Artificial Design Tutor—A Quest For Reframing Intelligent Tutoring Systems	[B]	[B1–2]

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ID	Venue	Stable identifier	Title	Questions	Sub-questions
246	E&PDE	10.35199/epde.2024.104	Use and application of generative AI in multidisciplinary projects: lunar habitacles, automotive concepts and future souvenirs	[A]	[A2–3]
247	E&PDE	10.35199/epde.2024.106	Speculative Design Through the Lens of AI	[C]	[C2]
248	E&PDE	10.35199/epde.2024.107	The boundaries of industry-academia interactions: first steps to prepare IAdesign education for society 5.0	[B]	[B2–1]
249	E&PDE	10.35199/epde.2024.110	The intersection of AI and bloom's taxonomy in design education: a robotic design case study	[A]	[A2–3]
250	E&PDE	10.35199/epde.2024.112	Experience of globally distributed design teams in a changing world	[B]	[B2–1]
251	E&PDE	10.35199/epde.2024.114	Engineering design – does AI change the path of evolution in methods & teaching?	[B]	[B2–1]
252	E&PDE	10.35199/epde.2024.116	computational team dynamics and creative tension balance index in new product development teams	[A]	[A1–1]
253	E&PDE	10.35199/epde.2024.119	The challenges of teaching creativity using Artificial Intelligence	[B]	[B2–1]

a stable identifier in which it can be accessed (DOI), and the research questions associated with it, in two levels – high level questions (referred to as simply as "questions"), and lower-level questions (referred to as "sub-questions"). Question and sub-questions are denoted by letters and numbers, in accordance with the classification system reported in Tables 7 and 8. Finally, note that a single record may correspond with multiple questions and sub-questions.

Appendix B

The proposed classification system is based on the previous work by Kahlon & Fujii (2025). For purposes of traceability, we report on the mapping of older categories onto new ones, including the specific changes made and the rationale for these. Table B1 provides an overview of the changes made and the subsumption of older overarching categories into new ones. Table B2 serves as a detailed record

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Table B1. Overview of taxonomy revision logic

Previous category			New category			
ID	Definition		ID	Definition	Explanation of change	Rationale for change
A	How can we organize our knowledge in design computing research on a meta-level?	→	C	How can we organize our knowledge in design computing research on a meta-level?	Notational change due to reordering (A→C)	Due to the precedence of explanation and application over organization (i.e., knowledge generated in attempts to explain designing or when applying it serves as inputs for organization
B	How can we explain designing from a computational perspective?	→	A	How can we explain any design-related phenomenon?	Notational change due to reordering (B→A) Explanation of design education was subsumed into the broader category of explanation (A)	Due to the precedence of explanation over application, as findings from category A serve as inputs to B Merging by higher-level conceptual similarity
C	How can we enhance our methods of designing?	→	B	How can we apply our knowledge for enhancing design processes?	Notational changes (C→B), (D→B)	Due to the precedence of explanation over application (that is knowledge from explanation activity is mobilized for application)
D	How can we build computational tools for design-related activities?	→			Enhancing methods, building tools and using our knowledge for teaching were subsumed into the new category of application (B), which focuses on knowledge *mobilization* in any design-related activity	All are normative activities in which we apply our knowledge to *change* our practices of design-related activities
E	How can we use our knowledge for teaching design?	→				

Table B2. Mapping of research question across taxonomies

Previous classification system			Matching items in new classification system	
ID	Question in previous classification system		ID	Question
A	*How can we organize our knowledge in design computing research on a meta-level?*	→	C	*How can we organize our knowledge in design computing research on a meta-level?*
B	*How can we explain designing from a computational perspective?*	→	A	*How can we explain any design activity?*
C	*How can we enhance our methods of designing?*	→	B	*How can we apply our knowledge to develop our practices/tools?*
D	*How can we build computational tools for design-related activities?*	→	B	*How can we apply our knowledge to enhance design-related activity?*
E	*How can we use our knowledge for teaching design?*	→	B	*How can we apply our knowledge to enhance design-related activity?*
A1	*How can we organize our knowledge concerning the explanation of designing as a process?*	→	C1	*How can we organize our knowledge concerning the explanation of design-related activity?*
A2	*How can we organize our knowledge concerning the development of tools for design-related activity?*	→	C2	*How can we organize knowledge concerning the enhancement of design-related activities?*
A3	*How can we organize our knowledge concerning computational approaches for design pedagogy?*	→	C3	*How can we organize knowledge concerning the field as a whole?*
B1–1	*How can we develop our lens for looking at designing from a computational perspective?*	→	A1–1	*How can we develop our lens for looking at designing from a computational perspective?*
B2–2	*How can we apply our lens to capture design knowledge unambiguously?*	→	A1–3	*How can we apply our lens to capture design knowledge unambiguously?*
B3	*How can we use computational approaches for testing hypotheses concerning designing?*	→	A1–3	*How can we obtain empirical knowledge about designing from the viewpoint of design computing?*
B4	*How can we learn about the impact of computational tools on designing*	→	A1–3	*How can we obtain empirical knowledge about designing from the viewpoint of design computing?*
C1	*How can we improve our existing methods?*	→	B1–2	*How can we create new approaches/ tools for design practice?*
C2	*How can we help practitioners select among existing methods?*	→	B1–2	*How can we create new approaches/ tools for design practice?*
D1	*How can we establish the technical infrastructure for developing computational tools?*	→	B1–2	*How can we create new approaches/ tools for design practice?*
D2	*How can we build tools for supporting design practice?*	→	B1–2	*How can we create new approaches/ tools for design practice?*

Continued

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Table B2. Continued

Previous classification system			Matching items in new classification system	
ID	Question in previous classification system		ID	Question
D3	*How can we build tools for supporting design pedagogy?*	→	B2–2	*How can we create new approaches/ tools for design pedagogy?*
D4	*How can we build tools for supporting design research?*	→	A1–3	*How can we build computational tools for inquiry into design?*
D5	*How can we build tools for supporting other design-related activities?*	→	–	*Removed (the nature of such activities is external to designing and thus out of scope)*
E1	*How can we use computational approaches in design pedagogy?*	→	B2–1	*How can we use our current computational approaches/tools in pedagogy?*
E2	*How can we learn about the impact of computational tools on design pedagogy?*	→	A2–3	*How can we obtain empirical knowledge about design pedagogy from the viewpoint of design computing?*

regarding the mapping of each question in the previous classification system onto a question in the newly proposed system. For clarification, a new category Z was introduced when it was found that two other categories, X and Y, share a joint purpose at a higher conceptual level. For example, enhancing our methods of designing (previously category C) can be seen as a part of the effort to change how we design. This also applies to our efforts to develop our tools (previously category D). Therefore, both were subsumed into the newly introduced category of applying our knowledge to enhance our design processes (category B under new notation). By contrast, when two items, X and Y, belong to a single parent, the same parent, Z, yet cannot be considered as conceptually identical in terms of the purpose pursued, a new low-level category is introduced. Conceptual similarity is evaluated by phrasing the difference between the questions pursued in the form of a single-sentence concise statement. For example, questions regarding using computational approaches for pedagogy (Li 2004) and questions regarding keeping our curricula up to date (Tsiliakos *et al.* 2024) are considered as conceptually different, as the latter does not necessarily involve *using* a computational approaches, but rather *developing* one.

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