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Creative Thinking in the Architecture Design Studio: Bibliometric Analysis and Literature Review

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Abstract: It is increasingly important for researchers and educators to find effective ways to stimulate students' creativity. In design education, the specificity of design, defined as open-ended problems and ill-defined problems, provides a special opportunity to improve creativity. Nevertheless, design education itself encounters other issues concerning creativity, such as not specifying in detail what creative design pedagogy should be. Thus, a comprehensive review of existing studies is needed to guide research in this field better. We used bibliometric analysis to provide information on literature statistics of the 658 articles published in design research–related journals between 1982 and 2022. An in-depth review of the 36 selected articles revealed the existing research on the design studio to investigate creativity from three perspectives: (1) creativity criteria and evaluation, (2) idea generation and development, and (3) pedagogy in the design studio. This study provides a roadmap for global educators and researchers focusing on pedagogy that enhances students' creativity in the design studio.

Keywords: creative thinking; design studio; design education; design research; bibliometric

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1. Introduction

Creativity is characterized by the ability to deal with ideas of expression and produce unique and useful results [1]. It is often qualified by its outcome but can be associated with a specific process that is likely to produce creative artifacts in design [2,3]. A creative design process is a special type of design that generates innovative ideas [2,4]. Guilford pointed out that creativity is closely related to the ability to reconstruct problems and reinterpret thinking, which leads to freedom from fixation when developing logical solutions [5]. New ideas emerge from a new combination of existing knowledge and ideas found in experiments. Designers can find solutions based on processes such as problem interpretation, memory exploration, and adoption of relevant knowledge [6]. Cross argued for a design way of knowing that was distinct from scientific and academic ways of knowing [7].

Creative design thinking can be a powerful way to motivate various design ideas by allowing an interactive understanding of ill-defined design issues [7–11]. Accordingly, many researchers and educators have attempted to find effective ways to stimulate students' creative thinking, and they emphasize the importance of design education [7–10,12–15]. Transitions between divergence and convergence thinking often occur throughout creative design idea generation [16]. Dorst studied the core of design thinking to generate ideas, defined reasoning patterns derived from design, and emphasized abduction as a basic reasoning pattern for creative thinking [12]. Enhancing creativity is crucial in design fields and helps students discover their visions, acquire core expertise and knowledge, and understand the professional philosophy and foundation of the design process [11]. Students can intensively demonstrate their creative skills while learning during the design process and engaging in communication, discussion, and knowledge acquisition methods [17]. Design thinking has become a way to lead students' creativity and innovation, teach creative problem solving, and improve or rediscover creative confidence [18,19].

In the university education environment, each field has its own basic characteristics. The architectural department is an active area where research, design, and implementation processes are based on interaction, sharing, and production at the forefront rather than on theoretical processes [20]. Creativity and spatial ability are representative cognitive abilities that are considered important in architectural and spatial design [21–24]. The architecture design studio is a unique educational area in which students require creative abilities and communication skills [25]. The design studios are the most fundamental course of architectural education where students acquire practical and theoretical knowledge and creatively transform that knowledge into a representation of design models [26,27]. Design education has a complex and contradictory structure based on comprehensive and abstract concepts. Nevertheless, it can be a powerful way to allow interactive understanding of ill-defined design issues and motivate additional design ideas [9]. The design studio approach consists of repetitive reflections and representations in the design process [28]. In terms of the education aspect, how new operative techniques change the role of creative thinking in the design studio needs to be identified rather than just experimenting with techniques [29].

One of the problems with architectural design education is the gap between knowledge acquisition and knowledge application in design studios [30–32]. Design is related to subjective creativity, but the empirical university paradigm emphasizes objective rationality in education [17,33]. Design education has generally been delivered to students through the subjective teaching method of teachers rather than through a systematic academic approach [34]. Design education tends to be ignored as an academic category from a general educational perspective that values logical and empirical education. Thus, design education should have an educational model with more academic methods to improve creativity because promoting creativity is an important issue, and interdisciplinary integration should be emphasized [35]. Against this background, in the area of design education, many studies related to education to enhance creativity are currently being actively conducted. To improve students' creativity in design education and develop a more rigorous and academic approach to design education, it is necessary to form an educational platform that can take potential thinking to the next level within a new educational paradigm based on creative experience according to university standards.

Based on the research content analyzed, we aimed to extract research trends that could be important in future design education by identifying keywords related to creativity that have been actively explored in design research. Therefore, this study sought to understand creativity in relation to the design studio, along with the integral relationships between (1) creativity, (2) design strategy, and (3) design education. The composition of this paper is as follows. Section 2 describes the applied methodology, while Section 3 addresses the results of the bibliometric analysis. Section 4 discusses the findings and Section 5 presents the conclusions.

2. Materials and Methods

The use of traditional review methods depends on the objectives of the review and the size and nature of the literature under review. Since bibliographic analysis and meta-analysis are both inherently quantitative, the differences can confuse some scholars. To clarify this distinction, quantitative methods can handle large quantities of literature but are relatively different in terms of usage. In particular, meta-analysis focuses on summarizing empirical evidence by analyzing the direction, intensity, and relationship between the effects. It is useful for solving open research questions with data closer to conclusive than reported in any single primary study [36]. In contrast, the bibliometric analysis summarizes bibliographic and intellectual structures in the field by analyzing social and structural relationships between different research components such as authors, countries, institutions, and topics [37]. Thus, this study employed a bibliometric methodology summarizing quantitative techniques on bibliometric data to facilitate an approach to scientific databases via the Web of Science (WoS) to obtain large amounts of bibliometric data using software such as VOSviewer. The WoS is one of the world's largest bibliometric databases for

peer-reviewed studies, and it delivers the results of various analyses and forms linked to VOSviewer. Therefore, it was considered an appropriate method for identifying evolving research trends in creative thinking in design research across disciplines. To achieve this, the bibliometric study was conducted over the following five steps [37]: (1) define the aim and scope of the study, (2) choose the techniques for the bibliometric approach, (3) collect the data for bibliometric analysis, (4) run the bibliometric analysis comprising performance analysis and science mapping, and (5) deliver the findings and discuss their implications for future research.

2.1. The Aim and Scope of the Study

This study aimed to contribute to future research directions on researchers' creativity in design-related areas by presenting and reviewing research trends to improve students' creativity in design studios. In addition, the bibliometric study delivers theoretical and methodological references to creativity in the design studio. Researchers can obtain an understanding of the gaps between different disciplines and obtain a variety of ideas about design education that enhances students' creativity. Thus, we conducted a literature review to capture the developing topics and emerging concepts in design education that were relevant to our research questions on creative thinking in design research. This study addresses the following main research questions:

RQ1. How can creativity in the design process be evaluated in students' work?
RQ2. What are some effective educational tools in the design studio to support the creativity of design concepts?
RQ3. What educational practices are found in design studios to enhance creativity?

2.2. Framework for the Study

Table 1 shows the selection process adopted and analysis of the study at each phase. In the first study-selection phase, a preliminary study was conducted based on the title, abstract, and keyword. In the second bibliometric approach phase, a descriptive and quantitative methodology analysis of traditional literature reviews from the WoS databases was conducted based on publication year, the number of total citations, the most productive authors and countries, and the co-occurrence network of author keywords.

Table 1. Flowchart summarizing study procedure.

Phase 1:	2.3. Study selection	(1) Selection of databases with bibliometric data: The WoS		
		(2) Selection of software tools for analysis: VOSviewer		
		(3) Selection of query wording and Boolean operators: ("creativity" or "creative thinking") and ("design studio" or "education") and ("architecture" or "urban design" or "built environment")	⇨	n = 709
		(4) Selection of timespan: 1982–2022	⇨	n = 708
		(5) Selection of document types: Journal articles and proceedings articles, excluding review articles	⇨	n = 685
		(6) Selection of language: English	⇨	n = 661
		(7) Screening	⇨	n = 658

Table 1. *Cont.*

Phase 2: Bibliometric approach	2.4. Bibliometric approach	(1) Descriptive bibliometric analysis of WoS research: Number of publication year		
		(2) Descriptive bibliometric analysis of WoS research: Total citations		
		(3) Descriptive bibliometric analysis of WoS research: The most productive authors and countries		
		(4) Descriptive bibliometric analysis of WoS research: Co-occurrence network of author keywords		
Phase 3: Bibliometric Analysis	3.1. Performance analysis	3.1.1. Converting data from WoS to appropriate format for bibliometric analysis: Publication years of relevant citations		
		3.1.2. Most cited publications in WoS search result		
		3.1.3. Most prolific authors in WoS database		
	3.2. Science mapping	3.2.1. Co-authorship analysis of authors: Mapping the scientific collaboration of authors, countries, and organizations		
		3.2.2. Co-occurrence—Keywords in WoS: Most frequently used words, author keywords, co-occurrence, network of authors' keywords	⇨	105 keywords out of 502
	3.3. Intervention methods of the studies	3.3.1. Creativity in design studio: Creativity criteria Creativity evaluation	⇨	n = 36
		3.3.2. Idea generation and development: Reasoning patterns Representation tools		
		3.3.3. Pedagogy in design studio: Design studio set-up Enhancing creativity		
	3.4. Overall review			
Phase 4:		Discussion		
Phase 5:		Conclusions and directions for future research		

The VOSviewer software is used for visualizing the bibliometric networks employing the data imported from the WoS data source. Figure 1 shows the process of the bibliometric analysis of the data extracted from the WoS using the VOSviewer software.

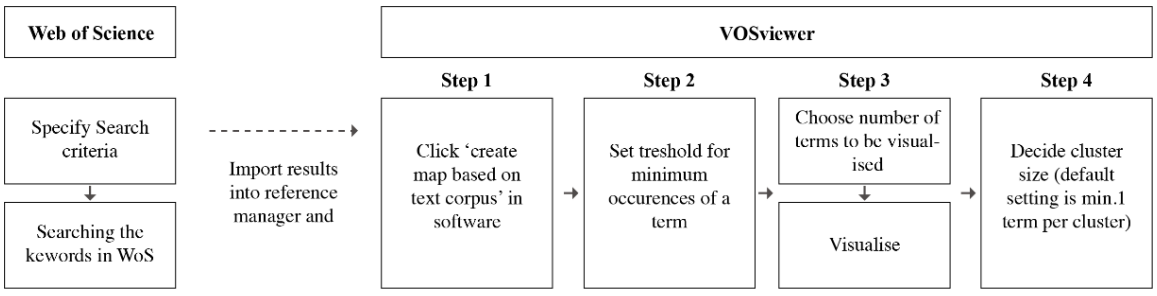


Figure 1. The process of the bibliometric analysis using the VOSviewer.

2.3. Study Selection: Phase 1

To ascertain the scope and ensure eligibility of existing studies on design research for creativity, we selected related articles from the WoS from 1982 to 2022 for further analysis using the keywords ("creativity" or "creative thinking") and ("design studio" or "education") and ("architecture" or "urban design" or "built environment"). The file

contained key information for literature analysis, such as author, subject, source, abstract, citation, document type, number of citations, keywords, and publisher information. We limited the results to articles and proceedings published in English. Intervention studies in peer-reviewed journals were included, whereas conference papers, essays, reports, and dissertations were excluded. These articles were judged based on their relevance and results. After several iterations, the keyword group consisting of terms to be excluded was applied to the databases. This search produced 658 articles. The selection criteria were as follows:

1. document types: journal articles and proceedings articles excluding review articles;
2. use of language: English;
3. publication year: from 1982 to 2022.

2.4. Bibliometric Approach: Phase 2

This study employed a quantitative bibliometric approach and was largely classified into qualitative and quantitative methodologies. In addition, from the traditional literature reviews available, this study focused on a narrow range of domain, method, and theory-based reviews using qualitative techniques [37–39]. The technical bibliometric approach from the WoS was categorized into four analysis techniques, as follows:

1. number of publications in a year;
2. total citations;
3. most productive authors and countries;
4. co-occurrence network of author keywords.

3. Results: Bibliometric Analysis

Bibliometric analysis is a common and rigorous method for exploring or analyzing large volumes of scientific data to discover new trends and examine the intellectual structure of specific areas in the existing literature [37]. First, performance analysis condenses the productive research components of the number of publications and citations per year, analysis of publications by journals, research area, authors, affiliations, and countries. Next, science mapping explores the relationships between research components categorized into five analysis techniques, as follows:

1. Citation analysis classifies the relationships between the most significant publications in the field of creativity in the design studio;
2. Co-citation analysis reveals the intellectual structure through publications, assuming publications that are cited together frequently are similar thematically;
3. Bibliographic coupling exposes periodical or current development of topics through the relationships between cited publications;
4. Co-word analysis discovers existing and future relationships between topics in the research area of creativity in the design studio;
5. Co-authorship observes the research network among authors and the equivalent impacts on the development of creativity in the design studio.

3.1. Performance Analysis: Phase 3 (1)

3.1.1. Publication Years of Relevant Citations

The 658 published research articles were analyzed, and the results are presented. Figure 1 reveals increased research in "creative thinking in the design studio" and presents indicators of publication activity based on records included in the WoS databases. It covers the number of publications (i.e., annual and cumulative) for the period of 1982–2022 and the number of citations that these items received. The data indicated that from 2010 to 2019, the number of publications of relevant citations increased considerably. However, the sharp decline in publications in 2021 and 2022 was due to unfinished bibliographic data records (see Figure 2). This trend will continue to demonstrate a rise in any future studies

conducted. Therefore, further analysis is needed to gain more insight into the direction of research in this area.

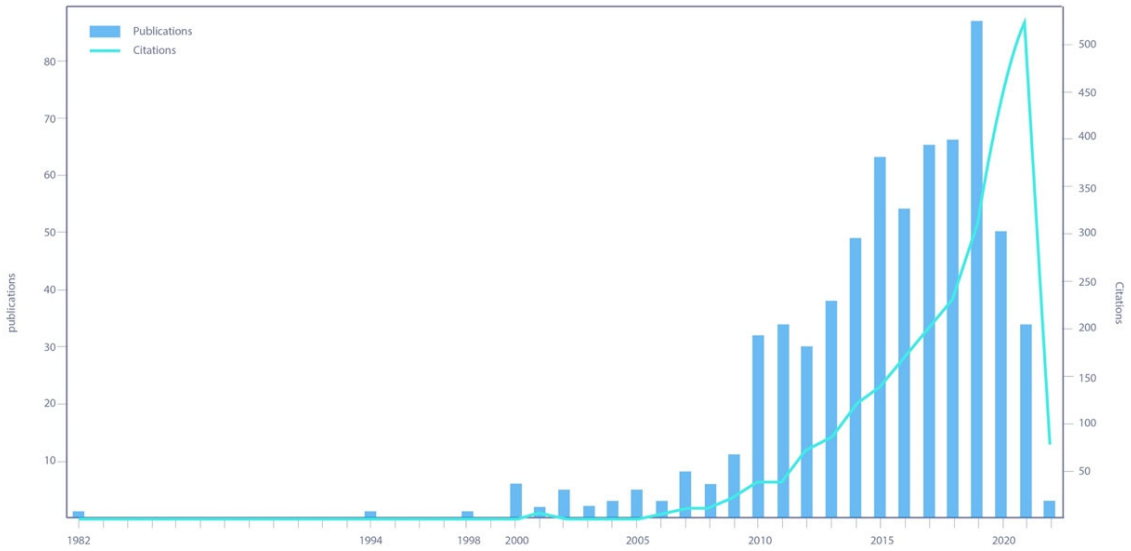


Figure 2. Times cited and publications over time.

3.1.2. Most Cited Publications

Table 2 shows the top 10 most cited papers in the WoS search results over the whole period from 1982 to 2022. The purpose of this analysis was to identify the main sources of ideas and determine which paper has had the most influence in shaping the content and the design research field. Moreover, we also present the research areas and number of the journals cited over the whole period, which indicates the change in the cited journals' influence on the design research. The most cited paper in the WoS databases, with 93 citations, was "How good are good ideas? Correlates of design creativity", written by Goldschmidt and Tatsa [40]. It should be noted that most studies on the lists with the highest number of citations were published in the journal *Design Studies*.

Table 2. The top 10 most cited papers in WoS search results for "Creative thinking for sustainable education in the design studio".

No.	Author(s)	Year Published	Paper Title	Journal	Discipline	Citation Count
1	Goldschmidt and Tatsa [40]	2005	How good are good ideas? Correlates of design creativity	*Design Studies*	Engineering	93
2	Goldschmidt and Sever [41]	2011	Inspiring design ideas with texts	*Design Studies*	Engineering	89
3	Ozkan and Dogan [42]	2013	Cognitive strategies of analogical reasoning in design: Differences between expert and novice designers	*Design Studies*	Engineering	66
4	Rahimian and Ibrahim [43]	2011	Impacts of VR 3D sketching on novice designers' spatial cognition in collaborative conceptual architectural design	*Design Studies*	Engineering	58
5	Kokotovich [44]	2008	Problem analysis and thinking tools: an empirical study of non-hierarchical mind mapping	*Design Studies*	Engineering	58

Table 2. *Cont.*

No.	Author(s)	Year Published	Paper Title	Journal	Discipline	Citation Count
6	Ibrahim and Rahimian [45]	2010	Comparison of CAD and manual sketching tools for teaching architectural design	*Automation in Construction*	Construction and Building Technology Engineering	57
7	Srinivasan et al. [46]	2016	Genetic markers of human evolution are enriched in schizophrenia	*Biological Psychiatry*	Neurosciences and Neurology Psychiatry	50
8	Demirkan and Afacan [47]	2012	Assessing creativity in design education: Analysis of creativity factors in the first-year design studio	*Design Studies*	Engineering	46
9	Cai et al. [48]	2010	Extended linkography and distance graph in design evaluation: An empirical study of the dual effects of inspiration sources in creative design	*Design Studies*	Engineering	46
10	Kowaltowski et al. [49]	2010	Methods that may stimulate creativity and their use in architectural design education	*International Journal of Technology and Design Education Psychology*	Education and Educational Research Engineering	45

3.1.3. Most Prolific Authors

The most productive authors with the most frequent contributions to the creativity in the design field in the WoS databases were Kim D.S. and Kim M.H., each with seven publications. Interestingly, South Korea was the most productive country in all periods (See Table 3).

Table 3. Most productive authors, organizations, and countries in the WoS database.

	Author	Institution	Country	Documents	Citations
1	Kim, D.S.	Kumoh National University Technology	South Korea	7	41
2	Kim, M.H.	Kyung Hee University	South Korea	7	25
3	Casakin, H.	Ariel University	Israel	6	53
4	Hua, C.H.	Kyung Hee University	South Korea	6	39
5	Cho, J.Y.	Kyung Hee University	South Korea	5	45
6	Hasirci, D.	İzmir University of Economics	Turkey	5	31
7	Lee, J.M.	Pusan National University	South Korea	5	21
8	Chen, Y.	University of South China	China	4	27
9	Dorado, M.I.A.	Universidad de Málaga	Spain	4	0
10	Huynh-the, T.	Kumoh National University Technology	South Korea	4	40

3.2. Science Mapping: Phase 3 (2)

3.2.1. Co-Authorship Analysis of Authors

Co-authorship analysis identified the intellectual collaborative structure of authors, countries, and organizations. The relationships between authors, countries, and organizations are displayed on the network map in Figure 2, and the links connecting the nodes represent the relationships. The size of the node characterizes the number of citations, while the thickness of the connection between the nodes establishes the strength of collaboration. Individual collaborative groups are assigned different colored circles.

(1) Authors

The threshold for bibliometric data was set as one for the minimum number of documents per author. Of the 1528 authors, only 33 met the threshold to create the collaboration network map shown in Figure 3. Nevertheless, co-authorship demonstrated that noticeable names from productive authors such as Goldschmidt, G., Kowaltowski, D., Demirkan, H., and Wang, T. had established firm research cooperative relationships.

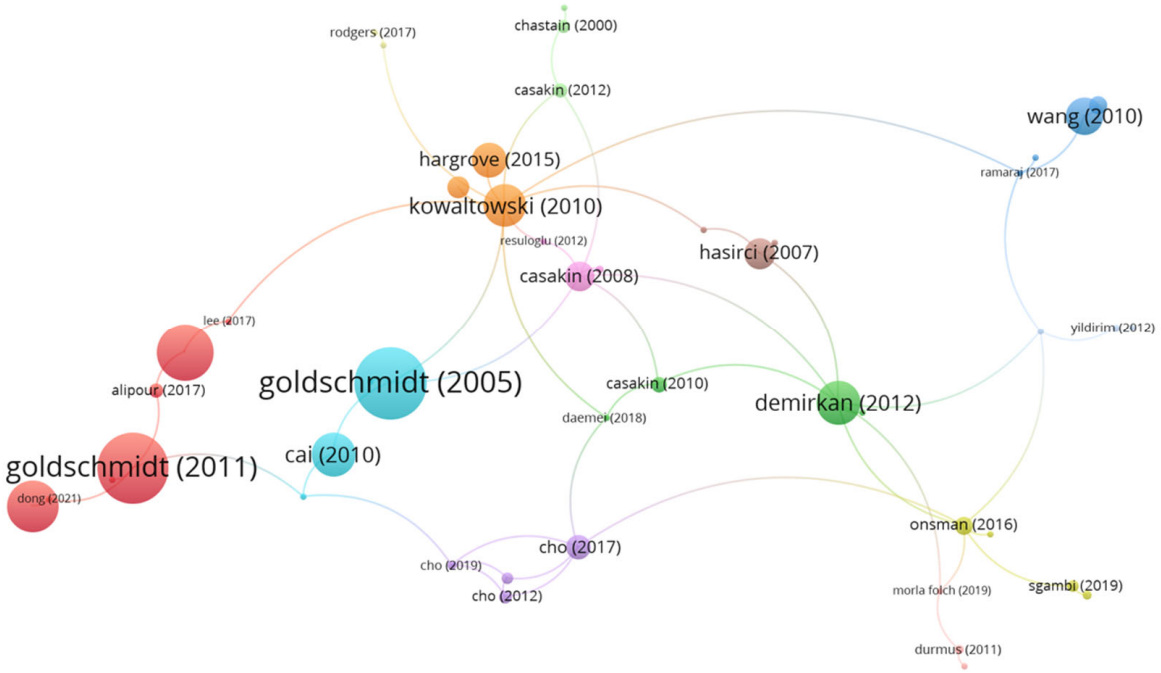


Figure 3. Mapping of authors' collaboration network.

(2) Countries

Regional collaboration and research hotspots were obtained with the visualization of co-authorship occurrences of countries. The distribution of studies across geographic regions appears in Figure 4. The size of the circles represents the number of occurrences of papers. Collaboration strength is demonstrated by the distance between circles in individual pairs. All studies were distributed internationally, with publications from all global regions. This suggests that the themes identified through the qualitative grounded theory analysis were likely to be general characteristics of studio pedagogy rather than specific to one nation's pedagogical tradition, thereby indicating an increasing trend of international collaboration among the authors. Analysis revealed 69 countries represented by collaborating authors in the WoS databases:

- Turkey and the United States had the greatest total link strength in relation to the international collaboration of authors;
- China, Spain, India, and South Korea had a high number of publications, but their international collaboration strength was relatively low.

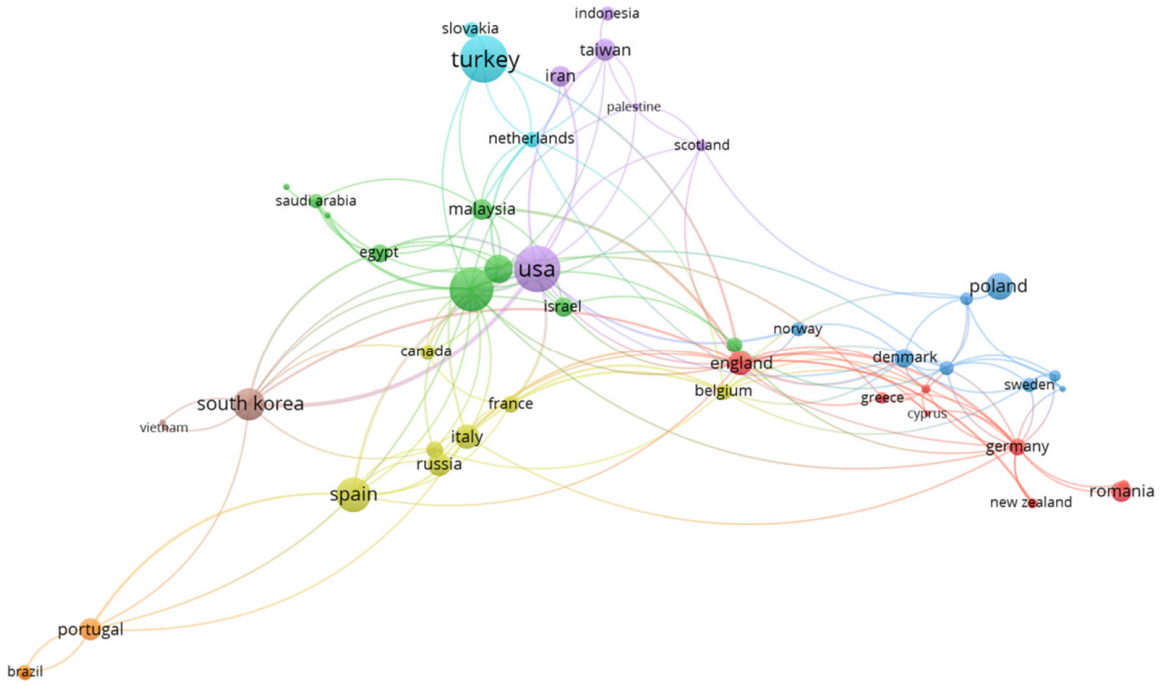


Figure 4. Co-authorship network of countries.

(3) Organization

To examine its international influence, we grouped the countries of the authors' affiliations into seven groups, displayed below in Figure 5. University Lisbon Ozyegin University, Mimar Sinan Fine Arts University, and Kyung Hee University appeared to have a relatively close network of relationships with other universities. However, the strongest relationship between Kyung Hee University and Pusan National University stood out.

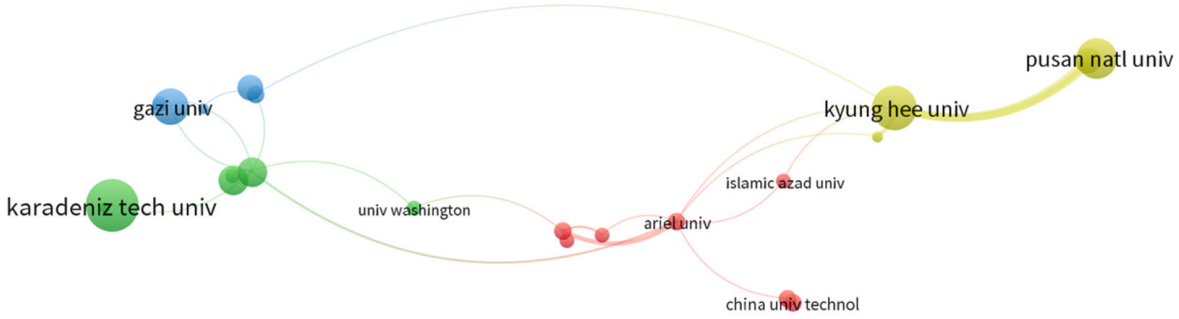


Figure 5. Co-authorship organization networks.

3.2.2. Co-Occurrence—Keywords Plus

The threshold for the co-occurrence of keywords was set to twice, and 105 out of 502 keywords were classified as visualization items. The keyword co-occurrence network is provided in Figure 6. The size of the circle corresponds to the number of occurrences of the illustrated keyword. The larger the circle, the more the author keyword was selected in the WoS databases. The subject similarity and its relative strength are demonstrated by the distance between the elements of an individual pair. Different colors of the circle are assigned to individual keyword clusters. The network in Figure 6 shows 12 individual clusters representing the individual subfields of the research fields identified in the WoS databases. The links between particular keywords indicate the number of papers in which the keywords co-occurred.

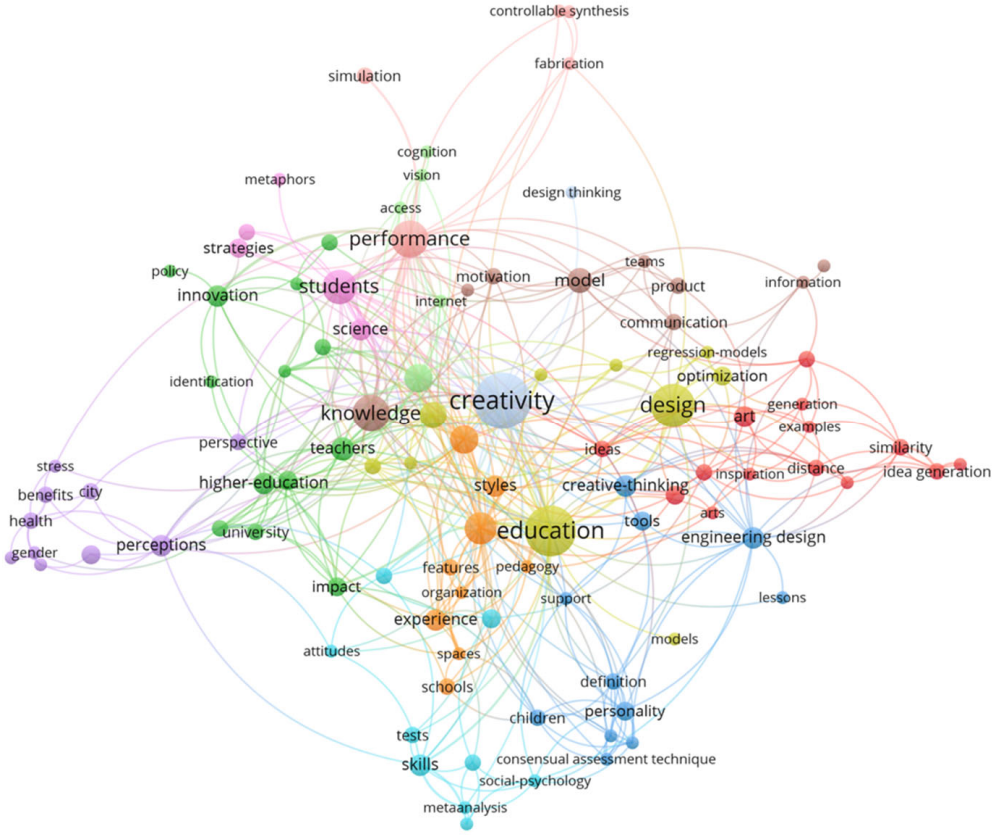


Figure 6. Co-occurrence network of author keywords (min. number of occurrences: two) in WoS.

Analyzing Figure 6, it may be concluded that the core topics with the highest total link strength were "creativity," "education," and "students." Twelve subfields (clusters of author keywords) were identified in the research fields, and the three main subfields were as follows:

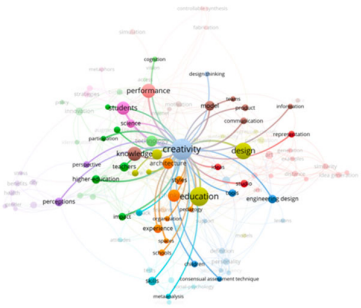
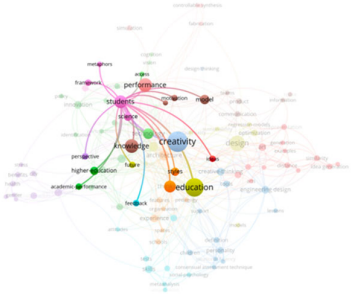
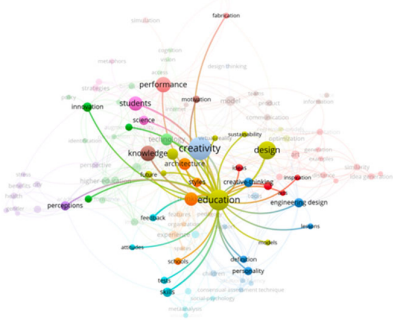
- Yellow cluster: Groups keywords such as creativity, design thinking, and experience;
- Pink cluster: Groups keywords such as design, tool, and sustainability;
- Brown cluster: Groups keywords such as education, knowledge, and challenges.

The results demonstrate a considerable diversity of the co-occurrence of author keywords in individual publications in the WoS, proving the multi-faceted and multi-dimensional character of this particular scientific field.

3.3. Intervention Methods of the Studies

In this section, the findings are discussed, focusing on the latest technology in creativity in the context of architectural design studios. The findings provide an overall explanation of the main topics identified primarily as important in the early stages of the design process, also known as the most creative conceptual stage of the entire design process. Before the establishment of creative design thinking as a term in the research field of interdisciplinary study, discussions focused on three aspects of research findings: (1) creativity criteria and evaluation, (2) idea generation and development, and (3) pedagogy in the design studio (See Table 4).

Table 4. Defining aspects of creativity, design strategy, and design studio.

Creativity	Design Strategy	Design Studio
		
Creativity criteria, Creativity evaluation	Idea generation, Idea development	Pedagogy

3.3.1. Creativity in the Design Studio

(1) Creativity criteria

Creativity is an individual's core ability to create original, useful, and unexpected tasks [1,50,51]. Therefore, rather than attempt to reach an agreement on how to define creativity, it may be more advantageous to review topics or characteristics related to how to understand creativity in a variety of contexts.

- Guilford emphasized divergent thinking and that creativity is closely related to reconstructing problems and defined fluency, flexibility, and originality [5];
- Goldschmidt argued that convergent thinking also plays a role in creativity, and design literature, which views design as a priori creative activity, mostly accepts this view [16];
- Doston argued that interest in design thinking was sparked in organizations that had difficulty dealing with complex problem situations, which could be particularly useful in the context of abductive reasoning in how design practices handled themes and frames [12];
- Taylor proposed five typologies of creativity: expressive, productive, inventive, innovative, and emergent [52];
- Jackson and Shaw reported specific topics of definition, including creativity, innovation, transfer, and application of ideas [53];
- Using qualitative analysis, Kleiman observed five categories of creative experience: constraint-oriented, process-oriented, product-oriented, transformation-oriented, and implementation-oriented [54];
- Cropley defined engineers as problem solvers, explained that the core activity of engineering is design, and suggested that creativity is inherent in the design process [55].

(2) Creativity evaluation

Many studies consider assessing creative outputs to discuss critical issues related to the measurement of students' activity. While efforts have been made to identify approaches to improving student creativity [56,57], there is no way to claim to be effective in student growth. The level of creativity in higher education is again related to the idea that the creativity practiced in higher education is deeply entrenched.

- Casakin and Kreitler emphasized the relationship between the evaluation of creativity in design problem solving and the level of expertise of evaluators [58];
- Hargrove and Nietfeld noted that evaluation played an important role in tracking students' conceptual understanding of the metacognitive process [59];

- Acikgoz evaluated the quality of learning achieved during the design team collaboration based on a rubric that included defining problems, idea generation, linking and integrating ideas, and adapting to the task at hand. He has shown that structured architectural processes significantly affect the overall consistency between design thinking, idea generation, and finding solutions [60];
- Choi and Kim enhanced novelty and familiarity measurement by using "third elements" that address ambiguous aspects such as clarity, communication, and observation to capture the behavioral aspects related to creative activities. The development of this triangular approach is worth considering in a very social and dynamic space [61];
- Grover et al. evaluated the support provided by typology in three key stages of the design process. Exploring the framing stage of a design project has shown that searching for relevant functions and identifying metaphorical typologies based on cultural, contextual, or empirical phenomena is challenging for most students [62].

3.3.2. Idea Generation and Development

Idea generation and development is the development of ideas and strategies that support various reasoning methods to influence students' design thinking in the design process and the expression of various techniques [7].

(1) Reasoning patterns

Analogical reasoning may be viewed as a critical aid in problem-solving, especially in solving architectural design problems. Metaphors can help designers understand unfamiliar problems and expand the scope of potential design solutions, especially in the early stages of the design process. Moreover, by examining the relationship between creativity and metaphor, it is evident that metaphor plays an important role in design creativity.

- Hofstadter revealed that analogy is a cognitive process that can support the acquisition of new knowledge [63,64];
- Dorst described abduction as a basic inference pattern for design strategies that define creative thinking. He studied the core of design thinking for idea generation, defined design-derived reasoning patterns, and emphasized abduction as the fundamental reasoning pattern for creative thinking [12];
- Casakin and van Timmeren revealed that analogical reasoning supports architectural education by employing visual and verbal analogies in the early stages of the design process [65];
- Schön argued that metaphor can help one reflect on the nature of a situation when solving unusual design problems. Without metaphor, it would be difficult to obtain solutions [27];
- Orthony emphasized that metaphor allows us to understand unknown situations in relation to familiar situations [66].

(2) Representation tools

Expressing creativity and visual experience is an essential part of architectural design. Design representations are used for a variety of purposes, including as a means of supporting reflective activities [67] and communicating design intentions to others [7]. Creativity can be developed through training, such as intentionally capturing new ideas [68–70].

- De Bono explained that brainstorming is a method for improving creativity and is a good example of enhancing and maximizing idea generation [71,72];
- Choi and Kim described how stimuli can generate thought extensions. Their work focused on the level of abstraction provided during brainstorming and troubleshooting, and the authors suggest that this can be particularly effective in digital contexts [73];
- Juhani emphasized that drawing refers to the essential meaning of revealing and embodying inner thoughts and emotions as much as recording the external world [74];

- Clear described that architectural drawings are traditionally considered to have two main functions: communicating practical information about design and constructing architectural projects, or communicating aesthetic information about building materials or stylistic aspirations [75];
- Park revealed that drawings represent a good medium for design and communication, and text could stimulate students' creativity as a thinking transition in architectural studios [29].

3.3.3. Pedagogy in the Design Studio

In the context of architectural design pedagogy, creativity-related education was emphasized as essential to producing self-sufficient and innovative future architects [76]. To this end, we identified (1) design studio set-up and (2) enhancing creativity to support creative education.

(1) Design studio set-up

- Goldschmidt and Tatsa analyzed student ideas generated during the development of a design studio project with additional ideas organized by fellow students and instructors. Their approach led to deep insights into how ideas are structured along the design process in terms of quality as well as quantity [40];
- Casakin and Kreitler compared the way students and teachers explored the design creativity process and outcomes. They found that while students focused on operational aspects, teachers paid more attention to innovative aspects of student processes and outcomes. They concluded that design studio intervention programs could consider these differences to facilitate the acquisition of design procedures and provide deeper insights into how students perceive design creativity compared to teachers [58];
- Asefi and Imani considered more broadly the "mode transitions" required to accommodate different types of thinking employed in different stages of the design process by using comparative studies of student outcomes. They advocated an active strategic education model and assigned various tools and methods for use in design studio work [76];
- Kowaltowski et al., from the perspective of an instructor, reviewed the creativity method and its use in a design studio. They interviewed 28 design instructors on how to apply it to design studios, reporting that the method is typically applied in an unstructured manner and that a more structured approach would help [49];
- Grover et al., used the historical theory of typology as a structured framework for the knowledge search contained in architectural building precedents to guide students through various stages of the design process. The design phase included frame definition, conceptual design, and detailed project development [62];
- Suh and Cho explored the relationship between an individual's cognitive style and creative performance by structuring the design process according to the different design stages. Their study found that intuitive students were more creative in the early stages, whereas adaptive and more analytical students improved their creativity at the end of the process [77];
- Kavousi et al., proposed a conceptual model that focuses on the impact of metacognitive processing in design education on student design thinking and making. Their research demonstrated how super-cognitive components interact and how they support training programs to improve the design process and creative outcomes generated [78];
- Avsec revealed that design thinking is closely related to self-directed learning and emphasized that creative design thinking can provide metacognitive insights that include interpersonal skills, creativity, and digital skills that are strongly explained by design thinking variables [79].

(2) Enhancing creativity

- Alterio and McDrury revealed that reflection on experience creates meaningful learning to improve creativity, interprets learning as behavior, and evaluates the results of these behaviors through self-reflection learning. This learning method shows that reflective practice trains students' creativity during studio projects [80];
- Hargrove and Nietfeld explored the effectiveness of creativity education in the form of associated thinking strategies. The pedagogical approach aimed at supporting creative problem solving consisted of integrating activities related to creative thinking strategies to encourage super-cognitive development. Creative thinking reflects the ability to be trained and developed over time [59];
- Bhattacharya et al., argued that active exposure to unusual experiences and/or situations can have useful creativity-enhancing applications in design studios. Their pedagogical approach was based on the idea that a conceptual mix of virtual scenarios can be used to enhance and train divergent thinking while dealing with a variety of unfamiliar and unexpected design situations [81].

(3) Problem-solving

- Kruger and Cross described that designers using problem-driven design strategies manage to produce the best results in terms of a balance between overall solution quality and creativity [82];
- Wrigley verified that design thinking creates a highly reflective creative process that allows students to review and critically think about their design process to create a deeper understanding of the evolution of design thinking as a problem-solving activity [83];
- Lee et al., revealed that the design process sometimes begins with solutions that are not problems through the empirical study of engineering designers with experience in successfully searching for problems that fit new technology solutions [84].

3.4. Overall Review

The characteristics of creativity in the design studio were considered, and three major themes and six subcategories were identified above in Section 3.3. The major themes included creativity, idea generation and development, and pedagogy in the design studio. The themes cover practical considerations that help architectural design studios' creative activities, as well as theoretical models and frameworks that underlie creativity interpretation in this context. The themes related to each category and directly addressed in the articles are shown in Table 5. Further, 36 selected articles are sorted by year and the remainder are organized by themes, and each sub-category sorts the description of each category.

Table 5. Overall review of the 36 selected articles.

Themes	Categories	Subcategories		Description	Articles
Creativity	Creative criteria	Divergent thinking	(1)	Emphasized fluency, flexibility, and originality	[5]
		Convergent thinking	(2)	Argued that convergent thinking also plays a role in creativity, and design literature, which views design as a priori creative activity, mostly accepts this view	[16]
		Abductive reasoning	(3)	Argued that abductive reasoning could be useful in dealing with open and complex problem situations, especially in the way themes and frames are handled	[12]
			(4)	Covered expressive, productive, inventive, innovative, and emergent typologies	[52]

Table 5. *Cont.*

Themes	Categories	Subcategories		Description	Articles
Creativity	Creative criteria	Typologies	(5)	Provided specific topics of definition, including creativity, innovation, transfer, and application of ideas	[53]
			(6)	Defined five categories of creative experience: constraint-oriented, process-oriented, product-oriented, transformation-oriented, and implementation-oriented by using qualitative analysis	[54]
		Engineering activity	(7)	Defined engineers as problem solvers, explained that the core activities of engineering are design, and suggested that creativity is inherent in the design process	[55]
	Creativity evaluation	Self-evaluation	(8)	Explored the relationship between the creativity assessment of design problem solving and the level of expertise of evaluators	[58]
		Metacognitive process	(9)	Constructed a mental model for a creative approach to design problem solving and evaluation of students' creative and metacognitive thinking through a final design project	[59]
		Structuring architectural processes	(10)	Evaluated the quality of learning achieved during the design team collaboration based on a rubric that included defining problems, idea generation, linking and integrating ideas, and adapting to the task at hand	[60]
		Third elements	(11)	Measured novelty and familiarity and addressed ambiguous elements such as clarity, communication, and observation	[61]
		Metaphorical typologies	(12)	Evaluated the support provided by typology in three key stages of the design process based on cultural, contextual, and empirical phenomena	[62]
Idea generation and development	Reasoning pattern	Analogical reasoning	(13)	Detailed a cognitive process that can support the acquisition of new knowledge	[63,64]
			(14)	Provided a basic inference pattern for design strategies that define inference patterns and provide creative thinking	[12]
			(15)	Used visual and verbal analogies in the early stages of the design process to support architectural education	[65]
		Metaphorical reasoning	(16)	Reflected on the nature of a situation when solving unusual design problems	[27]
			(17)	Focused on understanding unknown situations in relation to familiar situations	[66]
		Brainstorming	(18)	Discussed how this enhances and maximizes idea generation	[71,72]
			(19)	Covered how stimuli can generate thought extensions particularly effective in digital contexts	[73]
			(20)	Explored how this reveals and embodies inner thoughts and emotions	[74]

Table 5. *Cont.*

Themes	Categories	Subcategories	Description	Articles
	Representation tools	Drawings	(21) Studied communication of practical information and construction of architectural projects, or communication of aesthetic information or stylistic aspirations	[75]
			(22) Examined how text is used as a thinking transition in architectural studios—A good medium for design and communication	[29]
Pedagogy	Design studio set-up	Demonstrate	(23) Analyzed students' idea generations during the development of projects using additional ideas organized by students and instructors to demonstrate deep insights into how ideas are structured during the design process	[40]
		Comparativity	(24) Compared the design creativity process of students and teachers, finding that students focus on operational aspects, while teachers pay more attention to student processes and outcomes	[58]
			(25) Considered more broadly the "mode transitions" required to accommodate different types of thinking at different stages of the design process by using comparative studies of student outcomes	[76]
		Interview	(26) Interviewed 28 design instructors to examine the method of creativity and its use in the design studio, and suggested a more structured approach needed for the design studios	[49]
		Historical theory	(27) Used the historical theory of typology as a structured framework, including frame definition, conceptual design, and detailed project development	[62]
		Structuring the design process	(28) Explored the relationship between individual cognitive styles and creative performance	[77]
		Metacognitive process	(29) Proposed a conceptual model focusing on the role of metacognitive processing in design training programs to improve the generated design process and creative outcomes	[78]
			(30) Emphasized that creative design thinking can provide metacognitive insights that include interpersonal skills, creativity, and digital skills that are strongly explained by design thinking variables	[79]
	Enhancing creativity	Self-reflection	(31) Explored reflections on experience that create meaningful learning to enhance creativity, interpreted learning as behavior, and revealed that reflective practice trains students' creativity	[80]
		Super-cognitive development	(32) Explored an educational approach to supporting creative problem solving consisting of integrating activities related to creative thinking strategies to encourage super-cognitive development	[59]
		Active exposure	(33) Examined how a conceptual mix of virtual scenarios can be used to enhance and train divergent thinking while dealing with a variety of unfamiliar and unexpected design situations	[81]

Table 5. *Cont.*

Themes	Categories	Subcategories	Description	Articles
			(34) Designers using problem-driven design strategies manage to produce the best results in terms of a balance between overall solution quality and creativity	[82]
		Problem-solving	(35) Design thinking creates a highly reflective creative process that allows students to review and critically think about their design process to create a deeper understanding of the evolution of design thinking as a problem-solving activity	[83]
			(36) The design process sometimes begins with solutions that are not problems	[84]

4. Discussion

This study focused on the latest trends in creativity conducted in the context of architectural design studios. Architectural design studios are employed in the most practical courses in architectural education in which students acquire practical and theoretical knowledge and learn how to transform that knowledge creatively into their own spatial designs [27,85]. This study demonstrates that architectural design studios develop an understanding of the entire design process, which stimulates students' creative thinking. Teaching methods for creative design provide a holistic explanation of the key education related to teaching creativity in the context of architectural design studios. Creativity in design studios emerged from well-studied research themes that included Creativity, Idea generation and development, and Pedagogy in design studios. Each theme included categories which included Creative criteria and Creativity evaluation, Reasoning pattern and Representation tools, Design studio set-up, and Enhancing creativity and Problem-solving. The overall themes and their categories are presented in Figure 7.

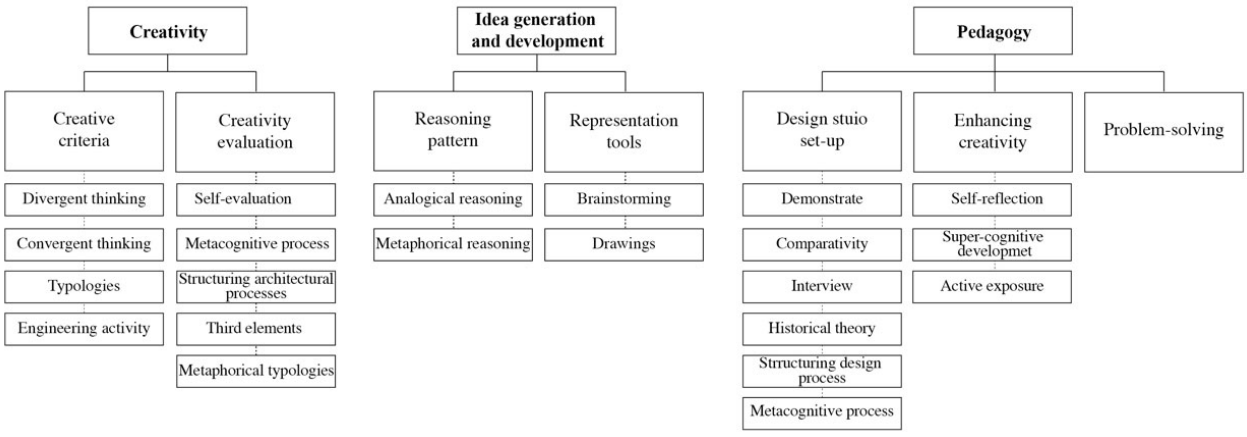


Figure 7. The overall themes and categories of the 36 selected articles.

In this study, How can creativity be evaluated in students' work in the design process? What are some effective educational tools in the design studio that support the creative design concepts? and What educational practices are found in design studios to enhance creativity? founded for answers to the initial research questions. Based on the answers to the research questions, some issues to be considered for enhancing creativity are identified.

First, according to recent studies, some interesting issues were found regarding the definition of creative criteria, including divergent thinking and typologies in design studios. In the context of the evaluation of creativity, we confirm a wide range of uses that stimulate students' creativity, such as self-evaluation, metacognitive processes, structuring

architectural processes, third elements, and metaphorical typologies. The approach to enhancing students' creative thinking consists of integrated activities related to creative thinking strategies. It emphasizes that creative thinking is the ability to be trained and developed over time [68–70].

Second, creative design strategies are a special type of design process that generate innovative ideas and creative artifacts in design [3,4]. Idea generation is possible because of the identification of new visual cues supported by interactive conversations established by designers between available external sources and internal representations of analogy and metaphorical reasoning patterns. It is suitable for use with advanced representation techniques. However, it is also recommended that the structure that supports activities be increased, despite individual reflection and perception of students. This may include the types of stimuli used to improve ideation, the background knowledge needed to support ideation, or the representation of ideas and concepts. Information can relate to users and contexts as well as stimulation and background technical information. How the tools and information used to manage them are manipulated afterwards is a key concern identified in this category. For a successful path through creative processes, students are required to reflect on their processes and explain them clearly in the work.

Last, design studios are highly constructivist, and instructors use a learner-centered approach rather than a teacher-centered approach. This constructive and open-ended approach is consistent with recent studies, and the teaching methods are more effective in enhancing higher-level learning outcomes [86]. Particularly, architectural education is a unique area that requires creativity, drives innovative ideas, and constructs cognitive receptive procedural perceptions that enrich creativity. Teaching methods for creative design deal with issues related to teaching creativity in the context of architectural design studios.

These issues stem from the nature of the creative process and lead to a loss of potential for students to learn creativity. In such cases, transforming the teaching methods of other subjects to promote creative learning outcomes is likely to cause similar problems for both instructors and students. These findings reveal problems that can arise when teaching methods lead to creative learning outcomes. Nevertheless, participation in conferences and educator networks and partnerships with certification bodies can facilitate the sharing of best practices and innovations for curriculum development and help implement these more broadly in the future.

5. Conclusions

The study examined the scientific flow of publications and citations over time and revealed prominent publications, prolific journals, research areas, authors, countries, and organizations related to creative thinking in the architecture design studios. Several bibliometric techniques, such as performance analysis and science mapping, were identified to investigate academic production, collaboration, and research topics. The review from an initial pool of 658 articles resulted in the analysis of 36 articles according to the main themes of creativity in design studios, which broadly reflected the issues of enhancing creativity in design education.

This study explored the characteristics of publications to contribute to the literature on creativity in design studios and to understand the developing research trends in this area. This study provides a solid foundation and contributes to related fields so that researchers may gain a comprehensive perspective, identify knowledge gaps, and derive fresh ideas for future study. We have specified examples of research in areas of immersion, presence, and social presence. However, many other areas, including architecture, will benefit from creativity in design studios. As our consideration of creativity continues to evolve, results from academic disciplines such as neuroscience, psychology, and sociology will inform future cognitive models and tools that support collaborative creative design activities. In terms of pedagogy, these new concepts and approaches could be constructed and developed in a way that is practical, feasible, and beneficial to the application of architectural design studios. The topics and issues presented in this study are intended to

provide the foundation for these surveys and to support the next generation of creative educators and architects.

As with other types of study, literature reviews have limitations, and many are related to the quality and quantity of original research and the quality of systematic consideration procedures. This type of review aims to provide an objective view of the literature, but there are areas where subjective decisions may be affected by bias, such as source selection and thesis review. In this study, the nature of many studies on the subject of creativity in architectural design studios meant that thorough examination and review were needed to reach full agreement on strictly relevant paper pools. While many studies have explored creativity, the literature related to the role of creativity in architectural design studios is relatively limited. This required additional searches for sources based on the researchers' experience, as well as reinforcement of the optimized search string used in WoS databases. This was a resource-intensive and time-consuming task that required high levels of motivation and persistence.

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