

Exploring Global Research on Fashion Pattern Innovation through Computer-Aided Design: A Bibliometric Approach

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ABSTRACT

The fashion industry is undergoing a digital transformation, particularly in patternmaking, where traditional methods face limitations in efficiency, precision, and scalability. Computer-Aided Design (CAD) has emerged as a key technology, yet global research on CAD-based fashion pattern innovation remains fragmented and underexplored. This study adopts a bibliometric approach using the PRISMA protocol to systematically analyze 124 Scopus-indexed publications from 2000 to 2024. Analytical tools such as Biblioshiny (R Studio) and Microsoft Excel were employed to map research trends, contributors, citation impact, and thematic developments. Findings indicate a moderate annual growth rate of 1.7% in publications. China, the United States, and France are the most active contributors, with journals like *Computer-Aided Design and Applications* serving as primary outlets. Highly cited studies emphasize virtual simulation, 3D editing, and anthropometric modeling. Co-occurrence analysis reveals dominant themes such as CAD, fashion design, virtual reality, and automation, indicating strong interdisciplinary convergence. This study contributes by mapping two decades of research, identifying global collaboration patterns, and highlighting emerging topics. The results offer practical implications for curriculum development, research prioritization, and digital innovation in the fashion industry. Despite limitations in data scope and sample size, the study establishes a foundational understanding of CAD's role in pattern innovation and calls for broader data inclusion in future research.

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1. INTRODUCTION

The fashion industry has undergone a profound digital transformation, with technological advancements permeating all aspects of creative and production processes (Sarker & Bartok, 2024). Among the most significantly impacted areas is patternmaking - the foundational element of apparel design and manufacturing (Ustazah et al., 2022). While traditional manual patternmaking retains artistic

value and craftsmanship, it faces limitations in efficiency, accuracy, and scalability. As the industry increasingly prioritizes speed, precision, and sustainability, the need for innovative pattern development solutions has become imperative. Consequently, digital technologies, particularly Computer-Aided Design (CAD), have emerged as strategic solutions to these challenges (Cheng et al., 2023; Kyratsis et al., 2025).

CAD technology has revolutionized design practices across various sectors, including architecture, engineering, and manufacturing. In the fashion industry, CAD enables designers to create, modify, and simulate clothing patterns digitally with a high degree of precision (Bui et al., 2025; Lee & Han, 2024; Mohamed, 2025). This technology also facilitates three-dimensional visualization, accelerates design iterations, and reduces the need for costly and material-intensive physical prototypes. Its impact is significant not only in improving production efficiency but also in supporting sustainability principles by reducing textile waste. Additionally, the use of CAD encourages designers to explore more complex forms and structures, thereby expanding the aesthetic horizons of contemporary clothing design (Alabi & Ogbolu, 2024; Goworek & Bailey, 2024).

The adoption of CAD in the fashion pattern innovation process has attracted the attention of academics from various disciplines, ranging from design, textile technology, industrial engineering, to computer science. Numerous studies have been conducted to examine the effectiveness of CAD in fashion product development, its impact on the design learning process, and its potential in supporting personalization and digital manufacturing (Hu & Liao, 2023; Ikubanni et al., 2022). However, these studies remain scattered and have not provided a comprehensive overview of how this topic is evolving globally. There are insufficient studies mapping the relationships among researchers, publication dynamics, and the thematic directions that are the primary focus in this field, resulting in a gap in the comprehensive understanding of the existing research landscape.

In addressing this gap, the bibliometric approach offers a systematic and quantitative method for evaluating and visualizing the dynamics of scientific research (Ahmad et al., 2023; Watrionthos et al., 2023). By analyzing metadata from publications available in leading databases such as Scopus, bibliometrics can reveal temporal trends, author collaborations, citation impact, and thematic relationships between studies (Fadillah et al., 2024; Samala et al., 2023). This method has been widely used across various fields to evaluate scientific progress, identify central figures in research networks, and trace emerging topics. However, to date, few studies have specifically applied bibliometrics in the context of CAD-based fashion innovation, despite the fact that such analysis is crucial for strengthening the theoretical and applied foundations of digital fashion design.

Methodologically, bibliometrics is capable of extracting data on a large scale and transforming it into visual maps and quantitative indicators that represent the structure and evolution of a field of study. By utilizing analytical tools such as Bibliometrix, researchers can identify thematic clusters, scientific collaboration networks, and correlations between concepts through techniques such as co-occurrence, co-citation, and bibliographic coupling. In the context of this research, this approach is expected to reveal patterns of CAD research development in fashion innovation, both in terms of knowledge production and interactions among scientific actors. The results obtained not only reflect the current state but also provide a strong foundation for formulating a more structured and responsive future research agenda aligned with the needs of the fashion industry.

The practical implications of this study's findings are quite broad. For the academic community, this analysis identifies areas of research that are still underdeveloped and opens up opportunities for strategic collaboration between researchers and institutions. For educational institutions, the results of this study can serve as a basis for developing a digital technology-based fashion design curriculum that is responsive to global dynamics. For the industry, this study presents promising research directions to support technology adoption strategies and innovation roadmaps. Additionally, policymakers and funding agencies can use this research trend map and gap analysis as a reference in setting priorities and allocating resources for the development of sustainable fashion technology.

Therefore, the main objective of this study is to identify and visualize various aspects of global research related to fashion pattern innovation through Computer-Aided Design (CAD) technology. This study attempts to describe the evolution of publications in this field, identify the most frequently cited documents, and map the countries, authors, institutions, and journal sources that are most productive in producing related scientific publications. Additionally, through keyword co-occurrence analysis, this study aims to explore thematic trends and conceptual issues that have emerged over the past two decades. To achieve these objectives, this research poses the following four main questions:

- RQ1. What are the main findings and publication trends revealed by the overview analysis in the bibliometric analysis?
- RQ2. Who are the authors, affiliations, countries, and research sources that have produced the most publications related to this topic?
- RQ3. Which research documents are most frequently cited by other researchers?
- RQ4. How is the co-occurrence analysis of author keywords related to this topic visualized?

2. METHODS

This study uses the PRISMA method and bibliometric analysis as a systematic and measurable methodological approach in reviewing the literature. The PRISMA method, known for its accuracy and standards in compiling systematic reviews and meta-analyses (Agrawal et al., 2024), applied to ensure that the study selection process is conducted transparently and accurately. To support the data analysis and visualization process, R Studio software is used through Biblioshiny and Microsoft Excel, which facilitates interactive and informative mapping of research trends (Muskhir et al., 2024).

All stages followed the PRISMA method, which includes the processes of literature search, screening, feasibility assessment, and data synthesis. This approach is applied to reduce potential bias and enhance the validity of the study's findings. The primary focus of this study is to map the development and direction of global research on the application of Computer-Aided Design (CAD) technology in fashion pattern innovation. Figure 1 visually illustrates the literature selection workflow, from document identification to the final selection of relevant studies for further analysis in bibliometric mapping.

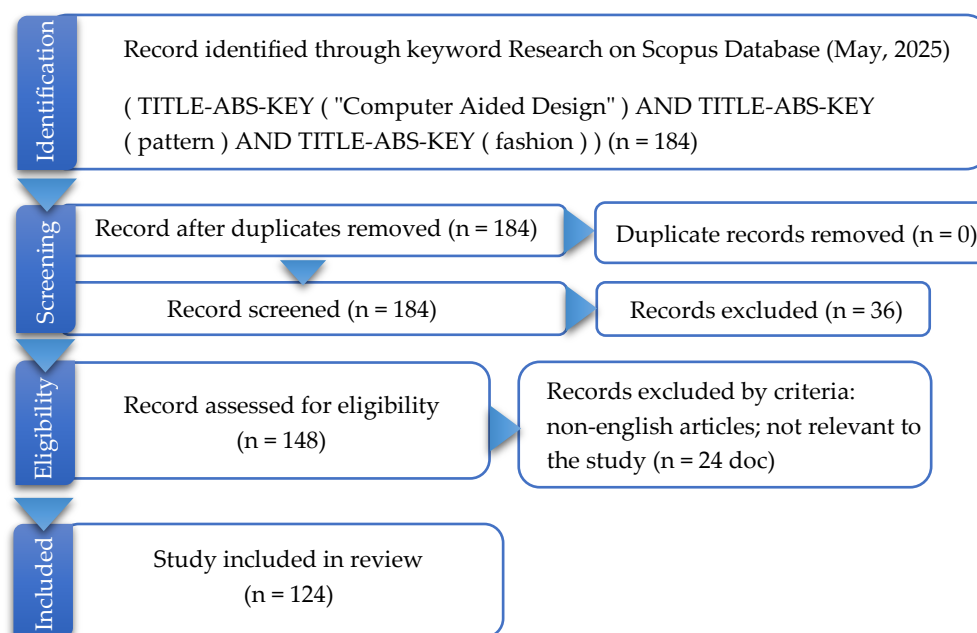


Figure 1. PRISMA flow diagram

Figure 1 shows the systematic literature selection process using the PRISMA approach in the bibliometric study in this research. The literature search was conducted through the Scopus database in May 2025 using a combination of keywords TITLE-ABS-KEY (“Computer Aided Design”) AND TITLE-ABS-KEY (pattern) AND TITLE-ABS-KEY (fashion). Scopus was selected for its superior features and vast coverage. The choice of Scopus is predicated on several primary factors, including the comprehensiveness and depth of the information provided, its esteemed reputation, robust citation network, consistency in data management standards, and its capacity for thorough and ongoing analysis (Gusenbauer, 2022; Pölönen et al., 2020).

From the initial search, 184 documents were obtained, and no duplicates were found, so all documents proceeded to the screening stage. After this initial process, 36 documents were excluded because they were not relevant to the study topic. 148 relevant documents were retained through careful screening, focusing on articles, proceedings, and years from the last decade to align them with current developments. Additionally, an in-depth screening based on document titles and abstracts was conducted. During the eligibility assessment stage, 24 documents were eliminated for failing to meet criteria—such as being written in a language other than English or having content irrelevant to the research focus, namely CAD-based fashion pattern innovation. Finally, 124 documents deemed relevant and of high quality were included in the bibliometric analysis. The final dataset was created for visualization, interpretation, analysis, and synthesis. Trends, challenges, opportunities, implications, and recommendations for integrating mobile learning into high school education. This approach ensures that research findings are based on accurate, relevant, and reliable data.

3. FINDINGS AND DISCUSSION

3.1. Findings

3.1.1 Overview

This study employs a bibliometric approach to analyze global research on fashion pattern innovation through Computer-Aided Design (CAD) technology, providing comprehensive insights into the field's development. Research Question 1 (RQ1) specifically examines core metrics and publication evolution through an overview analysis of bibliometric data. The analytical process commences with a systematic review of two critical dimensions: 1) fundamental metrics, and 2) publication trajectory analysis. The metric dimension captures key research landscape elements including publication volume, most productive authors, and leading journals or sources in CAD-based fashion pattern research.

The temporal analysis dimension elucidates publication growth dynamics, reflecting increasing scholarly attention to digital technology integration, particularly CAD, in fashion pattern design and construction processes. This trend underscores technology's growing centrality in the global fashion industry's transformation. Understanding these elements provides crucial preliminary perspectives for assessing the global, cross-temporal development of CAD-based pattern innovation research.

Furthermore, the dataset enables identification of major research contributions in the field, including: 1) author collaboration patterns, 2) institutional affiliations, and 3) geographical distribution of research outputs. Table 1 presents baseline information extracted from Scopus and Web of Science metadata, encompassing: publication timeframe, document count, source publications, annual growth rate, citation volume, contributing authors, single-author publications, and author collaboration ratios. These findings establish a foundation for understanding the dynamics and directional trends of global research contributions in CAD-based pattern innovation, particularly within the context of digital design technology advancement and technology-driven creative industry innovation.

Table 1. The main information on bibliometric analysis

Description	Results
Timespan	2000-2024
Sources (Journals, Books, etc)	94
Documents	124
Annual Growth Rate %	1,7 %
References	2227
Authors	342
Auhtor of single-authored docs	20

As evidenced by the data presented in Table 1, the bibliometric analysis of global publications on fashion pattern innovation through Computer-Aided Design (CAD) reveals an extensive temporal scope spanning from 2000 to 2024. During this period, the analysis identified 124 scholarly documents disseminated across 94 distinct publication sources, including journals, books, and other academic outputs. The annual publication growth rate of 1.7% indicates moderate yet consistent increases in academic attention to this research domain. The aggregate reference count of 2,227 citations demonstrates the substantive theoretical depth and breadth underpinning researchers' arguments in this field. Furthermore, the dataset comprises contributions from 342 unique authors, with 20 producing single-authored works, suggesting that while collaborative research predominates, individual scholarly contributions remain noteworthy. These findings collectively affirm that CAD-based fashion pattern innovation constitutes an emerging research field gaining increasing recognition across interdisciplinary academic communities over the past two decades. Following this general overview, the study further examines annual publication trends through Figure 1, which delineates the global research trajectory concerning CAD technology implementation in fashion pattern innovation.

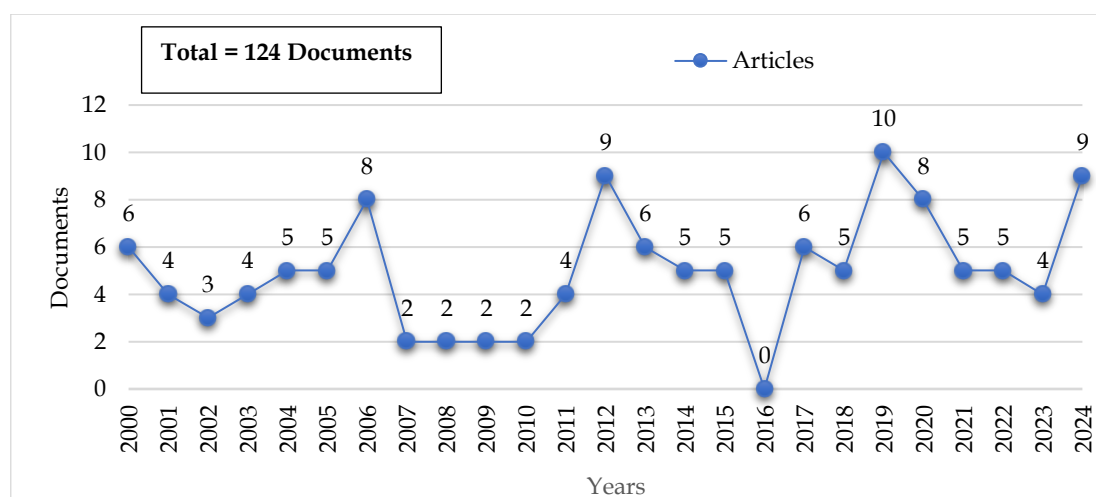
**Figure 2.** Evolution of publication (2000-2024)

Figure 1 illustrates the evolution of scholarly publications concerning fashion pattern innovation through Computer-Aided Design (CAD) from 2000 to 2024. The publication trend demonstrates a fluctuating pattern, characterized by significant surges interspersed with periods of stagnation. The data reveal relative stability in annual publication output, ranging between 3 to 6 documents during the early 2000s, followed by marked increases in 2006 (8 publications) and 2012 (9 publications), culminating in a peak of 10 publications in 2019. Notably, the complete absence of publications in 2016 potentially reflects either diminished academic interest or technological transitions within the field.

However, the subsequent resurgence in publication volume indicates renewed research engagement with CAD applications in pattern innovation.

This oscillatory growth pattern suggests sporadic development of the research domain, likely influenced by advancements in digital design technology and growing industry recognition of efficiency and precision imperatives. The observed fluctuations underscore the necessity for comprehensive bibliometric mapping to elucidate research dynamics, identify emerging trends, and pinpoint key contributors within this global research landscape. Such analysis proves particularly crucial for understanding the interdisciplinary evolution of CAD applications in fashion technology and establishing future research trajectories.

Implicating future research directions, the fluctuating publication trends call for a deeper examination of the underlying causes behind these oscillations, particularly in the context of technological advancements and industry needs. Moving forward, it is essential to explore how the increasing integration of Artificial Intelligence (AI), Machine Learning (ML), and automation into CAD can further enhance pattern development processes in fashion. Additionally, research should focus on bridging gaps between CAD technology and sustainability, with an emphasis on minimizing material waste and supporting eco-friendly manufacturing practices. As the fashion industry continues to prioritize customization and mass production, future studies must delve into the implications of CAD in enabling personalized, scalable fashion solutions. Collaborative research that combines insights from design, engineering, and computer science will be crucial in shaping the next phase of innovation in fashion pattern-making.

3.1.2 Top-productive authors, affiliations, countries, and sources

To answer Research Question 2 (RQ2), which focuses on identifying the most productive authors, institutional affiliations, countries of origin, and sources of publication in scientific works related to fashion pattern innovation through Computer-Aided Design (CAD), Table 2 shows the top five entries in each category. This table provides critical insights into the main contributors in the global research ecosystem in this field. These findings highlight the strategic role played by leading experts, academic institutions, and certain countries in advancing knowledge about the application of CAD in pattern design.

The analysis further reveals significant correlations between individual productivity, cross-institutional collaborations, and the function of publication venues as primary dissemination channels for research outcomes. These data establish a crucial foundation for understanding both the global research dynamics and emergent collaborative networks within the context of digital transformation in the fashion industry. Consequently, the rankings presented in Table 2 not only identify key knowledge production centers in this domain but also serve as a strategic reference for future research endeavors and potential scholarly collaborations.

Table 2. Top-productive authors, affiliations, countries, and sources

Rank	Authors	N	Affiliations	N	Countries	N	Sources (IF; Q)	N
1	Bruninaux, P	6	Lille Université (Prancis)	11	China	104	Computer-Aided Design and Applications (1,23; Q3)	6
2	Zeng, X	6	UCSF Center For Integrative Neuroscience (USA)	10	USA	82	International Journal of Clothing Science and Technology (1, Q3)	6
3	Chen, Y	4	Donghua University (China)	9	France	24	International (-; Non-Q)	5
4	Abteu, MA	3	Wuhan Textile University (China)	7	Romania	16	Advanced Materials Research (-; Non -Q)	3
5	Chen, L	3	Xi'an Polytechnic University (China)	7	Germany	15	CAD Computer Aided Design (3; Q3)	3

Table 2 presents the top five most productive authors, affiliated institutions, countries, and publication sources in global research on Fashion Pattern Innovation through Computer-Aided Design, as identified through bibliometric analysis. The analysis reveals Bruniaux P and Zeng X as the most prolific authors, each with 6 publications, followed by Chen Y, Abteu MA, and Chen L. Institutional affiliations demonstrate a predominance of Chinese universities, including Donghua University, Wuhan Textile University, and Xi'an Polytechnic University, alongside prominent institutions from France and the United States such as Lille Université and UCSF. This distribution suggests that research contributions primarily originate from nations with established technological research and development capabilities in fashion, particularly those focused on CAD integration in pattern design.

At the national level, China emerges as the leading contributor with 104 publications, followed by the United States (82), France (24), Romania (16), and Germany (15). Regarding publication venues, the journals *Computer-Aided Design and Applications* and *International Journal of Clothing Science and Technology* feature most prominently, each containing 6 relevant articles. Notably, while journals such as *Fashion Business International* and *Advanced Materials Research* fall within the Non-Q or unclassified category, they nevertheless serve as important dissemination channels for this research domain.

Collectively, these findings indicate that global research on CAD-based fashion pattern innovation exhibits three key characteristics: (1) multidisciplinary engagement, (2) cross-institutional and international collaboration patterns, and (3) publication across platforms with varying levels of scientific visibility. This tripartite nature of the research landscape underscores both the technical complexity of CAD applications in fashion and the diverse academic communities contributing to this evolving field.

3.1.3 Top 10 Most Cited Articles

To answer RQ3 regarding the identification of the most cited documents globally, the information can be found in Table 3. This table presents a list of the top 5 articles from a total of 70 publications discussing fashion pattern innovation through the use of Computer-Aided Design (CAD). The list includes details such as article titles, links or DOIs (Digital Object Identifiers), the total number of citations received, and a "TC per year" column indicating the average number of citations per year. This information provides a clear overview of the most influential literature contributions in this field and helps identify core references that serve as the primary foundation for research development related to CAD-based pattern design innovation.

Table 3. Top Five Most Cited Article

Title	DOI/Link	Total Cited	TC/Y ear
From early virtual garment simulation to interactive fashion design (Volino et al., 2005)	10.1016/j.cad.2004.09.003	161	7,67
From laser-scanned data to feature human model: a system based on fuzzy logic concept (Wang et al., 2003)	10.1016/S0010-4485(01)00209-3	126	5,48
Computer aided clothing pattern design with 3D editing and pattern alteration (Meng et al., 2012)	10.1016/j.cad.2012.03.006	84	6,00
Power-Aware NoCs through Routing and Topology Reconfiguration (Parikh et al., 2014)	10.1145/2593069.2593187	74	6,17
Virtual reality-based collaborative design method for designing customized garment for disabled people with scoliosis	10.1108/IJCST-07-2016-0077	51	5,67

Table 3 presents the five most-cited articles in studies examining fashion pattern innovation through Computer-Aided Design (CAD). The most frequently cited publication, "From early virtual

garment simulation to interactive fashion design," has accumulated 161 citations with an annual citation rate of 7.67, followed by "From laser-scanned data to feature human model: a system based on fuzzy logic concept" with 126 citations (5.48 citations/year). These seminal works underscore the critical role of digital technology integration in enabling precise, anthropometrically-responsive fashion design, thereby establishing themselves as foundational references in CAD-related fashion literature.

Of particular relevance to this research domain is the third-ranked article, "Computer-aided clothing pattern design with 3D editing and pattern alteration," which has received 84 citations (6 citations/year). This work substantiates CAD's pivotal function in facilitating interactive and efficient three-dimensional pattern manipulation. Notably, while the remaining two articles - focusing on efficient computing architectures and reconfigurable networks - demonstrate substantial citation impact, their primary orientation toward computer technology rather than garment pattern design suggests important interdisciplinary boundaries. These findings collectively indicate that despite observable interdisciplinary overlaps, the most influential scholarship in CAD-driven pattern innovation remains fundamentally grounded in virtual design and digital pattern processing methodologies.

3.1.4 Co-Occurrence Analysis

To answer RQ4 in the context of fashion pattern innovation through Computer-Aided Design (CAD), a co-occurrence analysis was conducted on the keywords provided by the authors in the analyzed articles. This bibliometric technique was used to identify major trends and thematic patterns in the global literature related to CAD-based fashion pattern design innovation. Through this approach, the most frequently occurring and intersecting research themes can be revealed, providing an overview of the direction of scientific development in this field. This analysis also helps trace how CAD technology is used in fashion pattern development and reveals the methodological focus and dominant areas of study in the last decade.

The co-occurrence method assumes that keywords that frequently appear together in scientific publications have strong thematic relevance. In the context of fashion design innovation through CAD, this technique is useful for identifying emerging topics, tracking the evolution of research over time, and projecting the future direction of this research. The results of this analysis not only reflect global research dynamics but also provide an important conceptual map for researchers to identify research gaps that have not been extensively explored. Thus, this information can be used to formulate a more focused research agenda and support the development of CAD technology in contemporary fashion education and industry.

need to examine the ethical and practical implications of their integration into fashion design, particularly regarding intellectual property, data security, and sustainability in mass production.

3.2. Discussion

The findings of this study indicate that research on fashion pattern innovation through the Computer-Aided Design (CAD) approach has seen consistent growth over the past two decades. Using a bibliometric approach, global publications on this topic have recorded an annual growth rate of 1.7%, a figure that, while not high, still reflects sustained interest from the academic community. This indicates that digital transformation in the fashion industry, particularly through CAD integration, has become a topic that is systematically explored and analyzed by the scientific community. A study by Tan & Li (2024) confirms that CAD plays a central role in providing opportunities for mass customization, time efficiency, and increased consumer satisfaction. The integration of CAD into the production and design processes of clothing enables the creation of more precise and complex designs in less time, while also supporting rapid adaptation to market trends. This development reinforces CAD's position not only as a technical tool but also as a strategic platform for driving innovation and productivity in the fashion sector (Casciani, 2024; Glogar et al., 2025).

The evolution of the number of publications between 2000 and 2024 shows fluctuations that reflect the dynamics of technology adoption in the fashion industry. Significant spikes in certain years, such as 2006, 2012, and 2019, indicate a strong correlation with advancements in digital technology and the emergence of new needs in the design process. For example, a study by Chipambwa et al. (2024) shows that the use of software such as CorelDraw and graphics tablets speeds up illustration and digital pattern creation, thereby supporting a more efficient creative process. Conversely, years of stagnation such as 2016 may reflect external challenges, such as limited access to technology, human resource readiness, or lack of research investment. These fluctuations are important to understand as they help identify critical moments that influence scientific interest, while also opening up space for evaluating research policies and the direction of technological development in the future.

Bibliometric analysis identifies individuals and institutions that actively contribute to scientific development in this field. Names such as Bruniaux P and Zeng X, as well as institutions such as Donghua University and Lille Université, occupy important positions in the production of CAD knowledge in fashion design. This is in line with the findings of Sola-Guirado et al. (2022), which highlight the importance of developing CAD technology competencies among educators and students to strengthen the education and innovation ecosystem. The dominance of China, the United States, and France in publications reflects a correlation between research and development (R&D) capacity and investment in higher education. Additionally, the involvement of journals from various rankings, including those not in the Q1 category, reflects a more equitable dissemination of knowledge, reaching practitioners and vocational communities, as well as academic elites.

The most frequently cited studies in this domain predominantly focus on digital simulation applications and pattern personalization using anthropometric data. Seminal works by Korosteleva et al. (2024) and Gill et al. (2024) demonstrate how 3D parametric editing accelerates design processes while enhancing pattern-to-body matching accuracy. This approach effectively bridges consumer demand for customized fit and industrial requirements for production efficiency. Such contributions establish critical theoretical and methodological foundations for subsequent research exploring CAD as an intelligent system within design ecosystems.

Keyword co-occurrence analysis reveals CAD's transformation into a multidisciplinary nexus within fashion design, connecting diverse fields including virtual reality, 3D graphics, automation, and machine learning. Research by Hassan et al. (2024) and Murugesan et al. (2024) highlights emerging technologies like digital textile printing and 3D computing in facilitating sustainable, cross-disciplinary design practices. These developments indicate CAD's conceptual evolution beyond technical applications into an integrative tool addressing multidimensional challenges in creative and technological industries. Consequently, future research trajectories will likely require intensified

collaboration among designers, computer engineers, and data scientists to develop more adaptive and predictive CAD systems.

The findings also emphasize the importance of educational institutions in adapting their curricula to reflect the evolving needs of the fashion industry. As the integration of CAD and other advanced technologies becomes increasingly central to design processes, educational programs must prioritize digital pattern-making skills, including proficiency in CAD software, 3D modeling, and customization techniques. This could involve updating design curricula to incorporate more hands-on training with these technologies, fostering collaborations with industry partners, and introducing specialized courses in digital fashion design. In doing so, educational institutions can better prepare students for the demands of a rapidly changing job market, ensuring that graduates are equipped with the skills required to thrive in the digital age of fashion design.

Collectively, this study substantiates that global academic exploration of CAD applications in pattern innovation significantly contributes to enhanced efficiency, aesthetic development, and design personalization. The bibliometric approach not only maps scholarly actors and distributions but also illustrates CAD's transformation into a cornerstone technology of modern design practice. As evidenced by Qiu & Liu (2024) and Conlon & Gallery (2024) CAD integration in education improves graduate preparedness for evolving industry demands. These findings carry strategic implications for both design curriculum development and the advancement of research-technology collaborations in the global fashion sector.

Methodologically, this study still has several limitations that need to be considered. One of the main limitations lies in the scope of the database used. Although Scopus is one of the largest and most globally recognized academic databases, reliance solely on Scopus limits the scope of literature that can be identified. Not all relevant publications, especially those a local journal, conference proceedings, or industrial technical documents, can be found in Scopus. Important literature that may be available on other platforms such as Web of Science or Google Scholar, or even from gray literature sources, may not be accessible to this study. Therefore, the results presented may not fully represent the entire research landscape on CAD-based fashion innovation.

Future research is recommended to involve more databases and types of publications, including conference proceedings and book chapters, to expand data representation and capture more variations in academic and practical contributions in this field. This approach will enable a more comprehensive mapping of trends, collaboration patterns, and research gaps, while improving the quality of the resulting bibliometric synthesis. Additionally, the timeframe analyzed in this study, from 2000 to 2024, also poses its own limitations. Although this span covers two important decades in the development of CAD technology, there is a possibility that early works that were seminal or foundational to the initial development of digital pattern design have not been fully accommodated. Therefore, a broader temporal scope in future research could provide a deeper historical understanding, enabling the identification of shifts in methodological directions, conceptual approaches, and research priorities over time.

Another limitation of this study is the relatively limited sample size of publications. While the number of articles analyzed is sufficient to describe general trends and contemporary research patterns, the use of a larger dataset in the future would be highly beneficial in uncovering more specific subthemes, institutional collaboration dynamics, and a more accurate geographical distribution of research. A broader dataset also has the potential to reveal emerging topics and provide a more nuanced analysis of the network of researchers collaborating in this field.

Therefore, to improve the validity and depth of future analyses, subsequent studies are encouraged to expand data sources, extend the research timeframe, and increase the sample size. These efforts will enrich our understanding of long-term developments in CAD-based fashion pattern innovation and open opportunities to identify under-explored research areas that require further exploration. Despite its limitations, this study still makes an important contribution as an initial

foundation for systematically mapping the global research landscape in the field of CAD-based fashion pattern design.

4. CONCLUSION

This study demonstrates that global research on fashion pattern innovation using Computer-Aided Design (CAD) technology has experienced steady growth over the past two decades. The findings reveal that CAD has evolved beyond being a mere design tool, positioning itself as a multidisciplinary platform that bridges various fields such as 3D graphics, virtual reality, and machine learning. These advancements highlight CAD's critical role not only in the fashion industry, driving innovation, efficiency, and customization, but also in shaping the future of design education. This reflects its growing importance as a strategic platform for both sectors, enabling more precise and adaptive design processes.

For the fashion industry, CAD's integration with advanced technologies such as 3D modeling and machine learning allows for faster production, more accurate fit customization, and a reduction in material waste, supporting both sustainability and scalability. The research suggests that future innovations in CAD will need to focus on enhancing these features, particularly in response to growing demands for mass customization. For educational practitioners and curriculum developers, this study provides actionable recommendations to modernize curricula. Educational institutions should prioritize the integration of CAD technology into design programs, offering hands-on training in digital pattern-making tools, 3D modeling, and other emerging technologies. Additionally, curricula should adopt cross-disciplinary approaches that combine design, engineering, computer science, and sustainability, ensuring that students are well-prepared to tackle modern fashion challenges. Close collaboration with the fashion industry is essential to align academic programs with the rapidly changing needs of the sector, ensuring a seamless transition from education to industry practice.

However, the study presents certain limitations in terms of database coverage, temporal scope, and sample size. Future research should address these limitations by incorporating a wider range of data sources, such as local and regional publications, conference proceedings, and industry reports. Expanding the analytical timeframe to cover earlier foundational works and emerging trends will also provide a deeper understanding of the historical evolution and future directions of CAD in fashion. Furthermore, a larger and more comprehensive dataset will reveal underexplored subtopics, such as the role of CAD in supply chain optimization and the impact of AI in predictive design systems. These improvements will strengthen the understanding of CAD-based fashion pattern innovation, enriching both academic theory and practical applications in education and industry.

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