EMERGING TRENDS IN THE USE OF IMMERSIVE TECHNOLOGIES FOR GARMENT DESIGN

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ABSTRACT

This study examines the applications of immersive technologies, such as virtual reality (VR) and augmented reality (AR), in apparel design. The aim is to identify current trends, advancements, gaps and opportunities for future research. A review of the literature has identified that these technologies enable designers to create digital prototypes, optimise creative processes and reduce material waste, thereby contributing to greater sustainability and efficiency in the fashion industry. However, research in this field demonstrates considerable fragmentation, which presents a challenge in integrating these advances into a coherent conceptual framework. While the adoption of AR and VR has grown, the implementation of advanced technologies such as artificial intelligence and machine learning remains limited. Furthermore, although sustainability is a relevant topic, it has not been sufficiently analysed in terms of its social and environmental impact. This study highlights the need for a more integrated approach and government support to encourage the ethical and responsible adoption of these technologies.

KEYWORDS

Immersive Technologies; Apparel design; Virtual reality; Augmented reality; Sustainability.

INTRODUCTION

The advent of immersive technologies, such as virtual reality (VR) and augmented reality (AR), has brought about a transformation in various industries, including fashion. These digital tools facilitate the generation of three-dimensional experiences that modify the design, prototyping, and marketing of clothing. In the field of textile design, these technologies facilitate the visualisation of designs in digital environments prior to their manufacture, thereby optimising both creative and production processes [1], [2].

In the field of fashion, these technologies provide innovative and sustainable solutions. The use of AR enables designers to collaborate in virtual environments, thereby reducing the necessity for physical samples and the subsequent material waste [3]. Conversely, VR is employed to simulate virtual catwalks and create immersive experiences for consumers, thereby eliminating geographical barriers and promoting accessibility [2].

The utilisation of these technologies enhances the efficiency of design processes by facilitating expedient and precise adjustments in real time. Furthermore, it encourages creativity by providing an array of tools to experiment with textures, colours, and shapes in an unlimited manner [4]. Consequently, immersive technologies transform the field of apparel design, while fostering a sustainable approach that is aligned with the current demands of the industry [5].

The research literature on the applications of immersive technologies in apparel design exhibits a notable degree of fragmentation, which presents a challenge in developing a consolidated conceptual structure. The absence of a unified framework that synthesizes the most salient advances impedes a comprehensive understanding of the subject and constrains the development of coherent lines of

research. While there are studies that explore specific aspects, such as the application of VR and AR to textile design, these have not been integrated into a systematic approach that allows for a comprehensive understanding of the subject [6], [7].

RQ1: What has been the evolution of the number of publications per year in this field?

RQ2: Who are the most influential authors and journals in this field?

RQ3: What are the most cited studies in research on immersive technologies applied to textile design?

RQ4: How are scientific publications on this topic geographically distributed?

RQ5: What are the emerging, growing and decreasing keywords in this field?

The originality of this study lies in its innovative approach, which proposes a new structure for the scientific body on immersive technologies applied to clothing design. This is achieved through an exhaustive analysis of the existing literature. This work updates the existing knowledge in a rapidly evolving field, identifying the emerging trends and gaps in research. By establishing a clear research agenda, guided by the advances and challenges identified, this study makes a significant contribution to the consolidation of a scientific framework that allows for a more comprehensive understanding of textile design with immersive technologies. This, in turn, paves the way for future explorations and the development of new solutions for the industry.

METODOLOGY

The methodology employed in this research is based on the PRISMA 2020 protocol, an updated guide for conducting systematic literature reviews [10]. This approach was selected for its capacity to facilitate a comprehensive and transparent analysis of the extant evidence pertaining to the applications of immersive technologies in apparel design. The utilisation of PRISMA guarantees the incorporation of pertinent sources and offers a unified and comprehensive perspective on the present state of the subject matter, whilst minimising potential biases in the review process, thus ensuring the dependability and validity of the outcomes obtained [11].

Eligibility criteria

The review included studies that addressed the application of immersive technologies, including VR, AR, mixed reality (MR), and related technologies (such as XR) in apparel design. Only studies of an academic nature, including systematic reviews and empirical research, were considered. To ensure the reliability of the findings, studies must be without time specificity and have access to the full text. The exclusion process was divided into three phases. The first phase excluded articles with errors in the indexing metadata. The second phase eliminated documents without access to the full text. The third

phase discarded those that did not directly address the application of immersive technologies in apparel design or that lacked practical implications in this field.

Sources of information

The research employed two databases, namely Scopus and Web of Science, which are widely acknowledged for their comprehensive coverage and high quality in the retrieval of scientific literature [12]. The Scopus database was selected for its extensive coverage of areas such as engineering, technology, and applied sciences, making it a key source for accessing articles on technological innovations in textile design. In contrast, Web of Science is renowned for its multidisciplinary database, which encompasses high-impact articles across a range of disciplines, including engineering and design. This makes it a valuable supplementary resource for acquiring pertinent insights on the utilisation of immersive technologies. The databases permit precise searches and access to high-quality articles, thereby ensuring the comprehensiveness of the review [13].

Search strategy

The search strategy was designed for each database with a structured equation that included key terms on apparel design and immersive technologies, such as "augmented reality", "virtual reality", "immersive technologies", "mixed reality" and "extended reality", along with the combination of terms such as "textile design", "immersive technologies", "fashion design" and "apparel design". This search was performed on key metadata such as title and keywords. This strategy was derived from the established inclusion criteria, ensuring that the search focused on published articles on the use of immersive technologies in apparel design.

Selection process

The selection process was conducted in several stages, as illustrated in Figure 1, which presents a comprehensive flowchart. First, searches were conducted in Scopus and Web of Science, employing the established inclusion and exclusion criteria. Subsequently, the titles and abstracts of the retrieved articles were evaluated to ascertain their relevance. Then, the full texts of the studies that passed the initial screening were analysed to confirm their compliance with the defined criteria. Finally, the selected studies were included in the systematic review, ensuring their quality and relevance to the research topic.

Data processing

The data were processed using Microsoft Excel, which is a standard tool for the management and analysis of large volumes of information. Following the selection of pertinent studies, the essential data
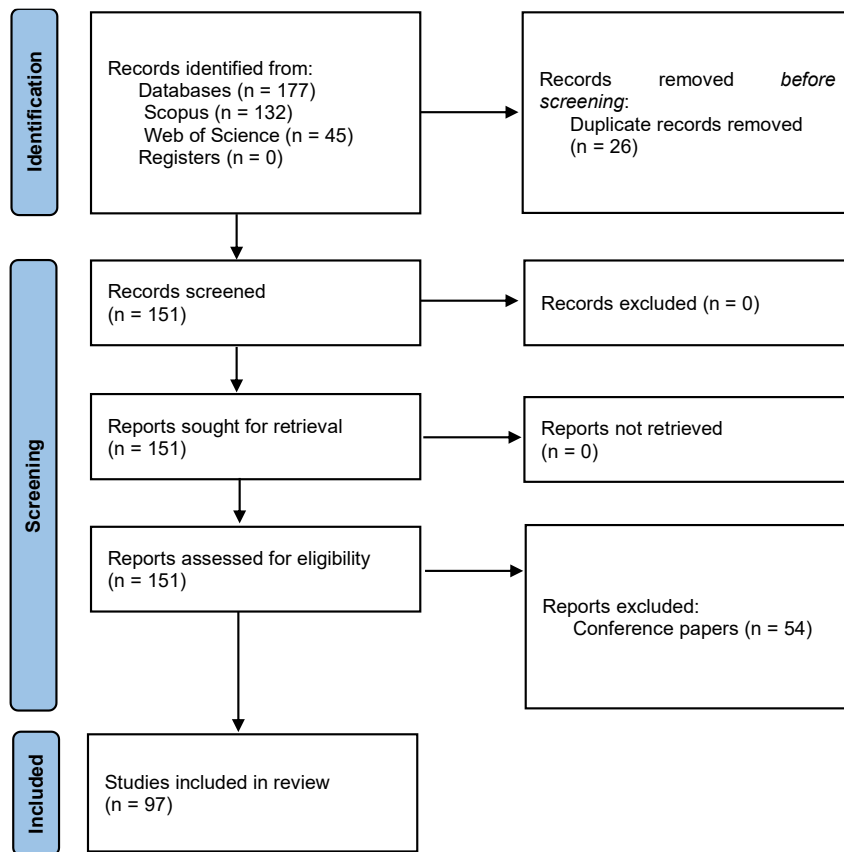
Figure 1. PRISMA flowchart. Own elaboration based on Scopus and Web of Science.

from each article were extracted, including the year of publication, the authors, the immersive technologies employed, the principal conclusions, and the areas of application in textile design. The data were subsequently organised in spreadsheets, thus facilitating their categorisation and comparative analysis. The Microsoft Excel software facilitated the efficient manipulation of data, as well as the visualisation of trends over time and the identification of research gaps and opportunities.

Risk of bias

The potential for bias in this study was mitigated through a meticulous process of article selection and evaluation, in accordance with the PRISMA 2020 protocol. In order to mitigate publication bias, two large and recognised databases were utilised. The databases Scopus and Web of Science were used to access a wide variety of studies, both in terms of authors and sources. However, the exclusive use of these databases and specific terms could have introduced biases, thereby limiting the scope of the search and excluding relevant studies from other sources or approaches. Furthermore, the potential for reporting bias was taken into account, as some studies may not have been published due to the absence of statistically significant results or editorial considerations.

RESULTS

The scientific literature on the applications of immersive technologies in apparel design dates back to 1996 and spans until 2024, demonstrating exponential growth with a coefficient of determination (R^2) of 0.9951, as illustrated in Figure 2. This value indicates a strong correlation between time and the increase in the volume of publications, thereby suggesting a stable and predictable trend. In recent years, there has been a notable increase in scientific production, with 13 articles published in 2021, 16 in 2022, 9 in 2023, and 14 in 2024. These findings underscore the mounting interest in the incorporation of immersive technologies into textile innovation, thereby reinforcing this domain as a pivotal focus for academic inquiry and industrial advancement.

The analysis of the principal authors in the field of immersive technologies applied to clothing design permitted the identification of three distinct groups, as illustrated in Figure 3. The first group, represented in orange, comprises authors with a high impact in terms of publications and citations. However, no authors were identified in this category. The second group, indicated in blue, comprises authors with a limited number of publications but a high number of citations relative to the average. This group is composed of the following authors: Boissieux, Cani, Wither, Cho and Kim, among others. The third group,
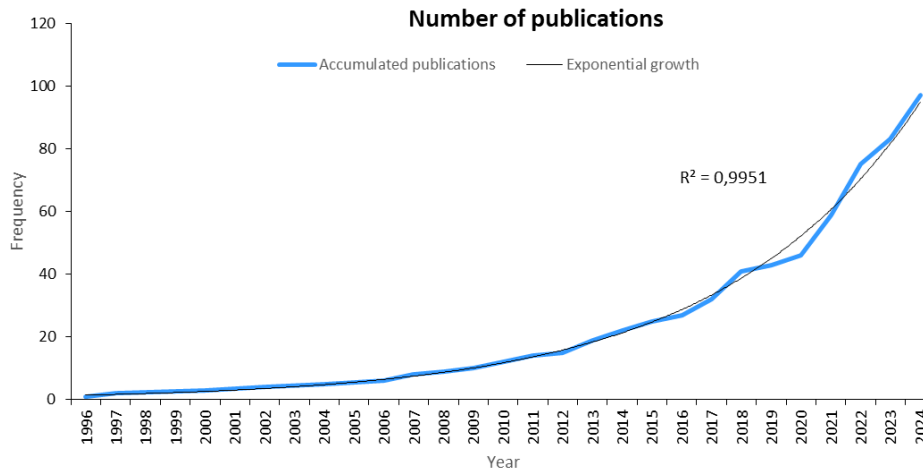
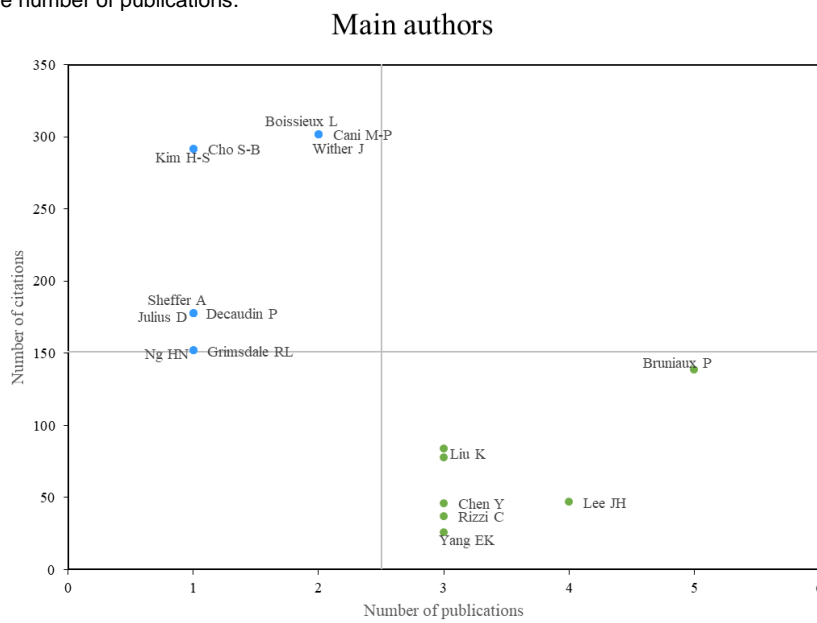**Figure 2.** Evolution of the number of publications.
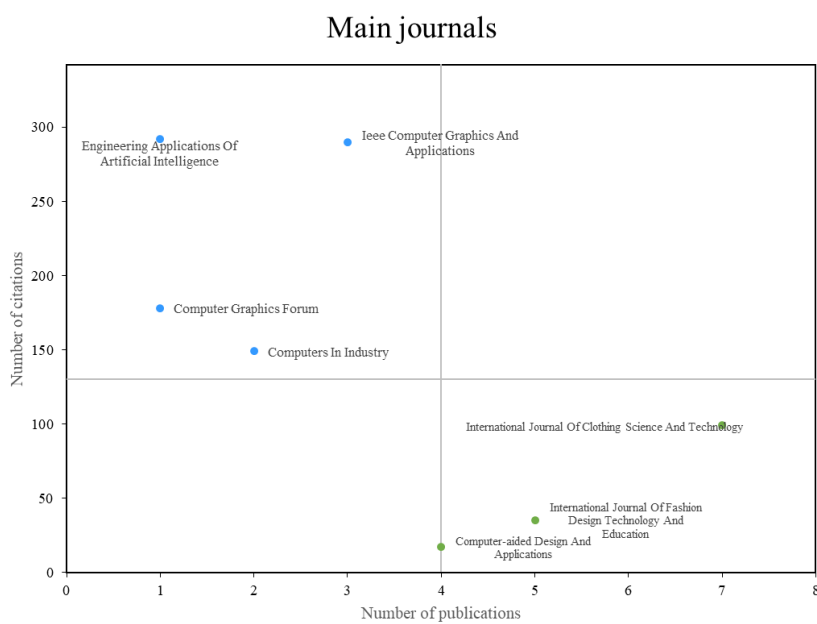

Figure 3. Main authors.

Figure 4. Main journals.

represented in green, comprises authors who have demonstrated high academic productivity, albeit with a relatively limited number of citations. This group comprises Bruniaux, Lee, Liu, Chen, Rizzi and Yang, who have made a significant contribution to the advancement of this field.

Moreover, an analysis of the principal journals in the field of immersive technologies applied to apparel design revealed the existence of three distinct groups, as illustrated in Figure 4. The first group, represented in orange, corresponds to journals with a high impact in terms of publications and citations. However, no journals were identified within this category. The second group, indicated in blue, comprises journals with a relatively low number of publications but a high number of citations in comparison to the average. These include IEEE Computer Graphics and Applications, Engineering Applications of Artificial Intelligence, Computer Graphics Forum and Computers in Industry. The third group, represented in green, corresponds to journals with high academic productivity, but with a low number of citations. In this group, the International Journal of Fashion Design Technology and Education, as the main representative, and Computer-Aided Design and Applications stand out.

This research presents an analysis of the ten most cited articles on the application of immersive technologies to the field of clothing design, as compiled in Table 1. The most notable studies are those of Kim and Cho [14], who applied an interactive genetic algorithm to fashion design, with 292 citations, and those of Decaudin et al. [15], who developed virtual garments. A Fully Geometric Approach for Clothing Design by Decaudin et al[15] is another notable study, with 178 citations and high academic impact. Other relevant works include Computer graphics techniques for modelling cloth by Ng and Grimsdale [16], with 152 citations; A survey on CAD methods in 3D garment design by Liu et al. [17], with 142 citations; and A sketch-based interface for clothing virtual characters by Turquin et al. [18], with 124 citations. Furthermore, recent contributions are examined, including Elfeky and Elbyaly's [19] "Developing skills of fashion design by augmented reality technology in higher education" and Hong et al.'s [20] "Design and evaluation of personalized garment block for atypical morphology using the knowledge-supported virtual simulation method," which illustrate the evolution and diversity of approaches in this field of study.

The global distribution of research on the applications of immersive technologies for clothing design, as illustrated in Figure 5, reveals a notable concentration in a few countries. China is the most prolific country in this field, with 40 publications, followed by South Korea with 9 and the United States with 7.

Other countries with lower production are Portugal (4), France (3), India (3), Hong Kong (3), Italy (3), Switzerland (2) and Canada (2). At the continental level, Asia is identified as the primary driver of this field, with notable contributions from China, South Korea, India, and Hong Kong. Europe also plays **a** significant role, with notable contributions from

Table 1. Main contributions in the literature

Title	Authors	Citations
Application of interactive genetic algorithm to fashion design	[14]	292
Virtual garments: A fully geometric approach for clothing design	[15]	178
Computer graphics techniques for modeling cloth	[16]	152
A survey on CAD methods in 3D garment design	[17]	142
A sketch-based interface for clothing virtual characters	[18]	124
A template of ease allowance for garments based on a 3D reverse methodology	[21]	61
Virtual reality-based collaborative design method for designing customized garment for disabled people	[22]	46
Developing skills of fashion design by augmented reality technology in higher education	[19]	41
Exploring the nature of digital transformation in the fashion industry: opportunities for supply chains, business models, and sustainability-oriented innovations	[23]	31
Design and evaluation of personalized garment block for atypical morphology using the knowledge-supported virtual simulation method	[20]	25

Trends in global research

Figure 5. Global distribution.
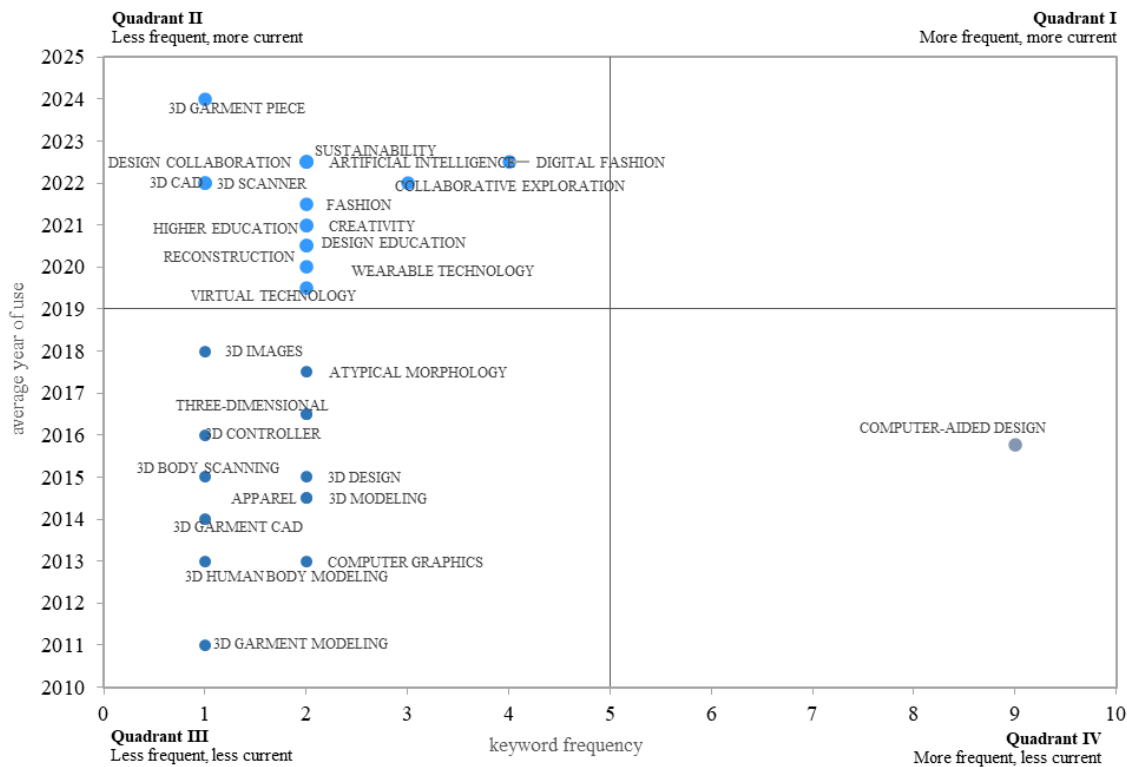
Keyword validity and frequency

Figure 6. Main keywords.

Portugal, France, Italy and Switzerland. In the Americas, the United States and Canada are the predominant contributors, while other regions demonstrate minimal or no engagement in this field. This illustrates an uneven geographical distribution, with Asia and Europe being the predominant regions.

Furthermore, a scatter graph was constructed to analyse the keywords associated with the utilisation of immersive technologies in the domain of clothing design. This is illustrated in Figure 6. The graph depicts the average year of use of the keywords on the y-axis and their frequency of appearance on the x-axis. This allows for the concepts to be classified according to their temporal relevance and level of research. Keywords situated in Quadrant 1 are characterised by a high level of recent research

activity and usage, which demonstrates their current relevance. The second quadrant encompasses emerging concepts, which exhibit a lower frequency of use but a recent average year of appearance, indicative of substantial growth potential. Keywords in Quadrant 4 are those that have been widely researched but whose average year of use is less recent, suggesting a possible shift towards other approaches.

The results demonstrate that no keywords were identified in quadrant 1, indicating the absence of concepts that exhibit both high frequency and timeliness. The second quadrant comprises emerging terms of interest, including 3D garment piece, sustainability, artificial intelligence, digital fashion and design collaboration, and others. These terms have recently emerged as relevant in the field. Keywords such as computer-aided design are identified in the fourth quadrant. Despite extensive previous research, this term shows a lower level of timeliness compared to more recent terms.

DISCUSSION

The discussion of this research is organised into several sections with the objective of offering a comprehensive analysis of the applications of immersive technologies in the design of clothing. Firstly, the results obtained are subjected to analysis and structured in a conceptual framework that facilitates their understanding. Secondly, they are compared with other relevant studies in order to identify similarities and differences. Thirdly, the existing gaps in the research are subjected to analysis, followed by a proposal for a future research agenda. Finally, the theoretical, practical and political implications, as well as the limitations of the study, are discussed.

Analysis of results

Theoretical development in the applications of immersive technologies in apparel design has undergone a remarkable evolution since 1996. In its nascent stages, research, as exemplified by Ng and Grimsdale [16], concentrated on fabric modelling techniques, with an emphasis on technical and visual aspects pertaining to geometric and physical precision. As the literature has grown at an accelerated pace in recent years, the approach has begun to incorporate consumer behaviour. More recent research, such as that of Lin, Li, and Xia [24], employs a psychological lens to examine the influence of factors such as novelty and sociability on consumer intent to purchase virtual garments. This shift reflects a transition from a technical approach to an analysis of the interaction between the consumer and digital fashion.

A review of the literature reveals three distinct groups of authors who have made significant contributions to the field of immersive technologies applied to apparel

design. The initial group, which combines both high production and high impact, is not represented by any authors in this study. The second group comprises Boissieux, Cani, Wither, Cho and Kim, who, despite having a relatively limited publication history, have a high citation impact. These authors have made notable contributions to the field of virtual garment design, particularly in the areas of physical simulation of clothing and 3D modelling [15]. The third group comprises Bruniaux, Lee, Liu, Chen, Rizzi and Yang, who have a high level of academic productivity, though their work has not yet achieved a significant impact in terms of citations. Nevertheless, their research, including that related to 3D modelling of garment fit parameters [25], continues to contribute to the advancement of virtual design models and customisation.

Similarly, an analysis of the principal journals on immersive technologies in apparel design reveals the existence of three distinct groups. The second group comprises journals such as IEEE Computer Graphics and Applications, which, despite a relatively low number of publications, has a high citation impact. This journal has been instrumental in the advancement of interactive interfaces for garment creation, as evidenced by a system that determines the shape and fit of garments to virtual characters using distances between the 2D silhouette and the 3D model [18]. The third group, characterised by high productivity but fewer citations, is represented by the International Journal of Clothing Science and Technology. This journal has developed a virtual reality-based method for designing customised garments for individuals with scoliosis, adapting the two-dimensional design to three-dimensional form [22].

The articles by Kim and Cho [14] and Decaudin et al. [15] represent seminal contributions to the field of immersive technologies applied to garment design. In their 2000 article, Kim and Cho introduced the concept of interactive genetic algorithms (IGAs) for the design of garments. By incorporating human response into the design process, they were able to overcome the limitations of traditional methods and facilitate adaptation to the ever-changing landscape of fashion. In 2006, Decaudin et al. proposed an intuitive system that converts 2D sketches into realistic 3D patterns, thereby generating developable surfaces for the creation of precise sewing patterns. Both studies are seminal in the evolution of digital fashion, integrating immersive technologies into the domain of garment design and enhancing interactivity and customisation.

Conversely, an examination of the geographical distribution of research on immersive technologies in garment design reveals a pronounced concentration in China, which spearheads academic production, followed by countries in Asia and Europe. In this context, the studies by Hong et al. [22] and Hong et al. [20], which originated in China, are of particular
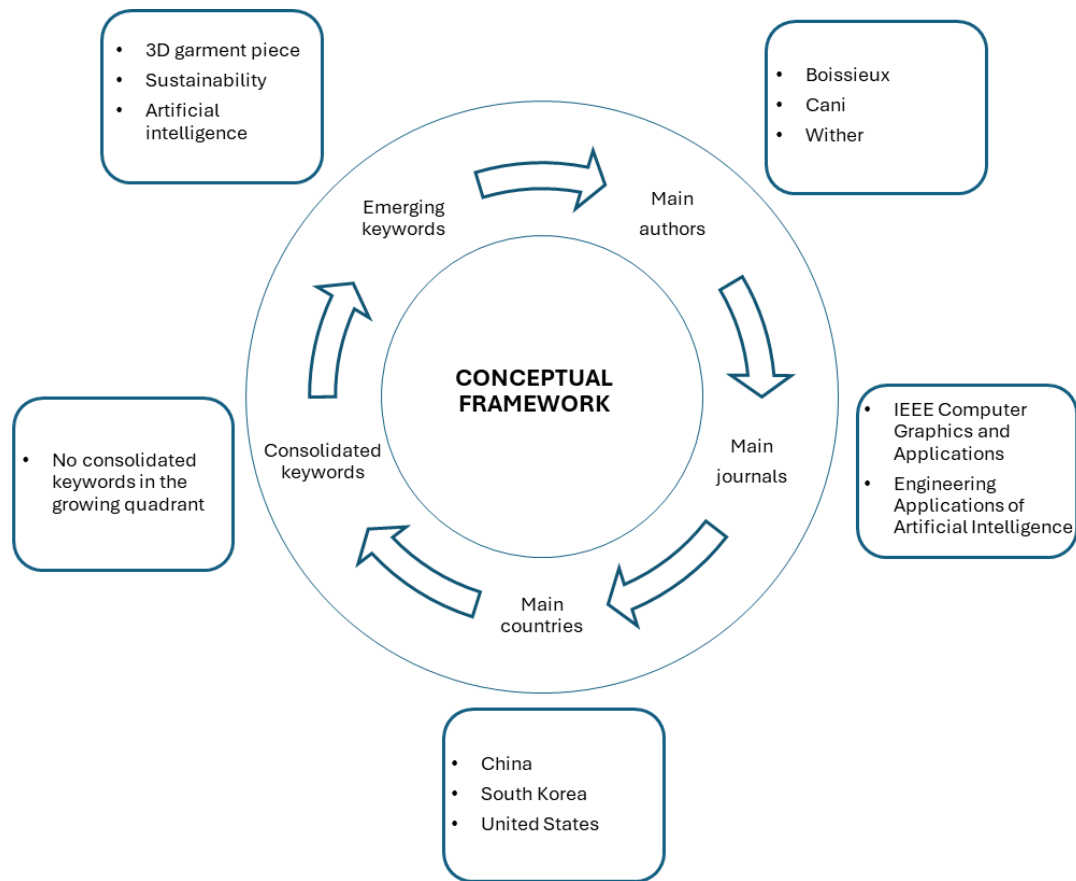
Figure 7. Framework of the scientific body.

significance. The first study presents a collaborative approach to the design of bespoke garments for individuals with severe scoliosis, utilising a virtual sensory evaluation procedure to enhance the 3D design of garments for atypical morphologies. The second study proposes a design process based on 3D to 2D virtual simulation, validating the efficacy and customisation of the design. Both studies emphasise China's leadership in the integration of immersive technologies, providing advanced and customised solutions with an emphasis on interactivity and inclusion.

The examination of keywords reveals the emergence of novel trends in the domain of garment design, as facilitated by immersive technologies. The quadrant of emerging terms includes concepts such as 3D garment pieces, sustainability, artificial intelligence, digital fashion and design collaboration, which are identified as having high growth potential. In their 2024 study on digital fashion, Lin, Li and Xia examine how virtual clothing design elements, such as novelty and sociability, affect the purchase intention of Chinese consumers. This highlights the relevance of digital fashion and its link to consumer motivations. Liu and Cheng [26] examine the role of artificial intelligence in fashion design, emphasising the integration of AI and virtual reality to anticipate trends and enhance design precision. They elucidate the influence of AI on the industry. The two studies

demonstrate the progression towards enhanced interactivity and personalisation in the domain of garment design.

Figure 7 presents a consolidated framework that synthesises and summarises the research results. This visual representation synthesises the key findings, offering a structured view of the main trends and relationships identified, facilitating comprehension of the most relevant elements of the study.

Comparison with other studies

The geographical distribution of academic production on immersive technologies in apparel design is consistent with the findings of Goel et al. [27], who also identify China as the leading nation in terms of publications, followed by the United States and France. Both studies emphasise China's pre-eminence in this field, indicating a pronounced focus on Asia for research on immersive technologies applied to fashion design. However, the current research provides greater detail by pointing out countries with lower participation, such as Portugal and Italy, which was not explicitly mentioned in the aforementioned study. Moreover, Puspitasari et al. [28] also identify the prominence of Asia and Europe, but concentrate on the evolution of virtual reality in fashion fairs, a more specific area of focus than the one addressed in the current study.

Table 2. Research gaps.

Category	Gap	Research Question
Technological integration	Lack of synergy between VR/AR and AI	How can the integration of VR, AR and AI optimize design processes, customization and consumer interaction in the fashion industry?
Sustainability	Little explored environmental impact	How can immersive technologies, such as VR and AR, contribute to more sustainable fashion design and reduce its ecological footprint in production and distribution?
Accessibility	Barriers for SMEs and emerging designers	What strategies can overcome economic, technological and training barriers in the adoption of immersive technologies in small fashion companies?
Consumer Experience	Limited interaction between consumer and technology	How do immersive technologies, such as AR and VR, affect brand perception and the purchasing decision process in fashion consumers?
Product customization	Limited real-time customization	How can synergies between VR, AR and AI facilitate real-time customization of clothing based on consumer preferences?
Ethics and sustainability	Insufficiently researched social and ethical implications	What are the social and ethical implications of the mass adoption of immersive technologies in fashion design and its impact on culture and employment?
Usability	Lack of studies on user experience in VR/AR	How can you improve user experience on virtual design platforms and what impact does this have on consumer satisfaction and loyalty?
Technology adoption	Limited research on technological barriers in small businesses	What are the technological and economic challenges faced by small businesses in adopting immersive technologies in fashion design?
Implementation in industry	Implementation in the production chain	How can immersive technologies, such as VR and AR, be integrated into the fashion production chain to improve efficiency and reduce waste?
Innovation in materials	Limitation in the integration of new technologies with innovative materials	How can immersive technologies like AR help in the development of new sustainable materials for fashion?
Collaboration between designers	Lack of collaboration between designers in virtual environments	How can collaboration between designers, using virtual environments and AR, enrich the process of collaborative fashion design and creation?
Manufacturing processes	Implementing VR/AR in manufacturing	How does the implementation of immersive technologies impact garment manufacturing processes, from design to production?
Market research	Lack of data on consumer acceptance	What factors influence consumers' acceptance of immersive technologies in the fashion sector and how do they affect their purchasing behavior?
Efficiency in design	Efficiency in garment design with VR/AR	How can immersive technologies such as VR and AR increase efficiency in the fashion design process, reducing time and costs?
Interaction in stores	VR/AR integration in physical stores	How can augmented reality and virtual reality be integrated into physical stores to improve the shopping experience and increase customer satisfaction?
Education and training	Need for training in immersive technologies	How can fashion designers be better trained in using immersive technologies such as VR and AR to enhance creativity and productivity?

In terms of keywords, the bibliometric findings of this study diverge from those of Goel et al. [27] who have identified terms such as "virtual reality" and "augmented reality" as being particularly prevalent. However, this study indicates that concepts such as "artificial intelligence" and "digital fashion" are becoming increasingly prevalent, while other established terms, such as "computer-aided design," are losing relevance. This trend is not explicitly referenced in studies such as Pawitan et al. [29], which focuses on the advances of virtual reality in the fashion industry specifically.

Ultimately, while the study by Sajovic et al. [30] concentrates on smart textiles, a comparable interdisciplinary approach and accelerated growth of research in fashion-related technologies is also evident. This serves to reinforce the relevance and dynamism of the field, albeit with a different focus on materials technologies as opposed to immersive technologies.

Research gaps

Table 2 delineates the principal research deficiencies in the domain of immersive technologies deployed in the context of clothing design. These gaps encompass a range of areas, from the integration of VR, AR and AI, to issues of sustainability, accessibility and consumer interaction with these technologies. They reflect key aspects that require attention to advance knowledge and facilitate the effective implementation of these innovations in the fashion industry.

Research agenda

The study of the applications of immersive technologies in apparel design is establishing itself as an innovative field that combines current technological trends with the needs of the fashion industry. It is recommended that this research agenda focus on areas that present both high development potential and gaps that still require attention in order to drive the adoption and evolution of these technologies.

One of the most promising areas of research is the application of 3D technologies in the creation of garments, including the development of 3D garment pieces and the enhancement of visualisation and functionality. It is imperative that research addresses the integration of these technologies into efficient design processes, with a particular focus on the creation of personalised garments and the optimisation of the consumer experience through virtual try-ons. Similarly, research should investigate how cost reduction in prototyping and production can contribute to a more agile and economical creative process.

The concept of sustainability is also gaining prominence. The incorporation of immersive technologies, such as virtual simulations and the utilisation of digitally enhanced materials, presents the possibility of reducing waste in the design and production phases. Nevertheless, there is a dearth of comprehensive studies examining the environmental and social implications of these techniques. Research should concentrate on how these technologies can optimise the use of sustainable materials in garment design, evaluating their feasibility and ecological consequences.

Furthermore, the development of AI in the realms of design customisation and fashion trend prediction represents a significant area of interest. Nevertheless, an examination of the extant literature reveals a dearth of studies investigating the integration of AI with immersive technologies, such as AR and VR. It is imperative that research addresses the manner in which these systems can be integrated to enhance the real-time customisation of garments and consumer interaction, which has the potential to transform both the design processes and the shopping experience.

Moreover, digital fashion has demonstrated considerable growth, particularly within virtual environments and the utilisation of digital garments on platforms such as video games and social media. This phenomenon necessitates research into the ways in which immersive technologies can facilitate the coexistence of digital fashion with traditional fashion, as well as how they could expand the possibilities of interaction between consumers and brands. The investigation of methods by which AR and VR can enhance the user experience in both virtual and physical environments represents a field of considerable interest.

Finally, it is imperative that further exploration be conducted into the essential aspect of collaboration in design. The utilisation of immersive technologies, such as 3D collaborative platforms, has the potential to transform the interaction between designers, engineers and consumers, thereby enabling the emergence of novel forms of real-time co-creation. Nevertheless, there is a paucity of research examining the ramifications of such collaborations and how they can facilitate innovation and creativity in the fashion industry.

In terms of gaps in the literature, several significant gaps have been identified. Despite the growing prevalence of virtual and augmented reality in fashion design, there is a paucity of research examining their integration with technologies such as artificial intelligence and machine learning. This limitation impedes the development of synergies that could optimise personalisation and consumer interaction. Moreover, while some studies have addressed the impact of digital technologies on sustainability, the current literature does not adequately address the environmental and social implications of their large-scale implementation.

Another significant gap in the literature concerns the accessibility of these technologies for designers and smaller-scale companies. The majority of studies have focused on large brands, thereby neglecting the economic, technological and educational barriers faced by emerging designers and small businesses in adopting these innovations. Furthermore, consumer interaction with immersive technologies has not yet been explored in depth, especially with regard to the influence on brand perception and purchasing decisions.

Implications

From a theoretical standpoint, the findings of this study contribute to the advancement of theories in the field of fashion design and immersive technologies, thereby broadening the understanding of the interaction between digital design and immersive tools. This approach integrates virtual reality, augmented reality and artificial intelligence, thereby facilitating the exploration of hitherto uncharted dimensions of creative processes, garment customisation and design collaboration. Furthermore, the research highlights deficiencies in the existing literature with regard to the sustainability and ethical implications of these technologies, underscoring the necessity for the development of theoretical frameworks that assess their environmental and social impacts.

From a political standpoint, the research underscores the necessity for the formulation of public policies that encourage the responsible and accessible utilisation of immersive technologies in the field of fashion. It is recommended that governments implement tax incentives or subsidies for small and medium-sized enterprises, which face significant economic and technological barriers. Furthermore, the study suggests the implementation of regulations that promote the utilisation of virtual prototypes as a means of reducing waste within the industry. Additionally, it proposes the establishment of regulatory frameworks that provide guidance on the ethical use of artificial intelligence and the customisation of products in virtual environments, with the objective of ensuring the protection of data and consumer rights.

In terms of practical implications, the results have direct implications for the work processes of designers and fashion companies. The incorporation of immersive technologies, such as virtual prototyping and fit testing in immersive environments, will facilitate a reduction in the time required for the creation process, a decrease in costs, and an enhancement of the consumer experience through real-time customisation. This approach will prove advantageous to both established brands and emerging designers and small companies, who will be able to gain access to previously inaccessible technologies.

Limitations

A significant limitation of this study is the methodological approach, which concentrated on a literature review and qualitative analysis. This may have resulted in the exclusion of more comprehensive or representative empirical studies of the industry. Moreover, the interpretation of the results may be subject to bias due to the lack of data on the actual adoption of immersive technologies in companies of varying sizes, particularly in small and medium-sized enterprises. It is important to consider these limitations when attempting to generalise the findings, as the research did not cover all contexts or practical applications of immersive technologies.

CONCLUSIONS

The study on the applications of immersive technologies in apparel design demonstrates the emergence of a new and promising field that combines technological innovation with creativity in fashion. The increase in research in this field reflects the growing academic and industrial interest in exploring the intersection between these technologies and textile design, thereby opening up new opportunities for customisation and sustainability in the industry. Nevertheless, significant shortcomings persist, particularly with regard to the integration of technologies such as artificial intelligence and machine learning, which have the potential to enhance design and customisation processes. Furthermore, there is a need for a more in-depth examination of the environmental and social impact of sustainability in fashion design.

The accessibility of these technologies for designers and small businesses also represents a challenge, necessitating an inclusive approach in future research. From a theoretical perspective, this study broadens the perspectives on digital design, proposing a more fluid integration of virtual reality, augmented reality and artificial intelligence. Government support is also crucial to promote the responsible and accessible use of these technologies, encouraging sustainability and ethics in their implementation. This field has significant potential to transform the fashion industry, with implications for both practice and theory.

Data Availability Statement: *The data may be provided free of charge to interested readers by requesting the correspondence author's email.*

Conflict of interest: *The authors declare no conflict of interest.*

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