

AI-ASSISTED PRESERVATION AND CONTEMPORARY TRANSFORMATION OF ISLAMIC GEOMETRIC ART IN PAKISTAN'S TEXTILE DESIGN INDUSTRY

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ABSTRACT

Islamic geometric art represents a highly structured visual language grounded in symmetry, repetition, and mathematical precision, forming a core element of Islamic cultural heritage and textile traditions. In Pakistan's textile design industry, this heritage is increasingly being reinterpreted through artificial intelligence (AI), particularly generative models, machine learning systems, and computer-aided design tools. This study investigated the role of AI in preserving the structural integrity of Islamic geometric art while enabling its contemporary transformation into innovative textile designs. A mixed-methods research design was employed, combining quantitative survey data from textile professionals with qualitative insights from design experts. The findings revealed that AI significantly enhances design innovation, productivity, and pattern generation capabilities; however, concerns remain regarding the loss of cultural and symbolic meaning when AI operates without human oversight. The study further established that human-AI collaboration is essential for maintaining cultural authenticity while maximizing creative potential. Regression analysis confirmed a strong positive relationship between AI adoption and textile design outcomes, explaining a substantial proportion of variance in innovation performance. The study concludes that AI can serve as a powerful tool for heritage-aware textile design when integrated with cultural knowledge frameworks and human expertise, particularly in contexts such as Pakistan where traditional textile arts remain culturally significant.

Keywords: Islamic geometric art, artificial intelligence, textile design, generative AI, cultural heritage preservation, Pakistan textile industry

INTRODUCTION

Islamic geometric art represents one of the most sophisticated visual systems in global art history, characterized by mathematical precision, recursive symmetry, and abstract representation grounded in spiritual philosophy. Historically, these patterns have been extensively applied across Islamic architecture, manuscripts, ceramics, and textile

traditions, reflecting a unified aesthetic language that avoids figurative depiction while emphasizing infinity, balance, and unity (Bonner, 2017; Broug, 2021). The structural logic of Islamic geometric design—based on grids, polygons, tessellations, and proportional systems—makes it uniquely compatible with computational modeling and algorithmic generation, positioning it as an ideal

candidate for artificial intelligence (AI)-driven design transformation.

In contemporary design ecosystems, AI has emerged as a disruptive force reshaping creative industries through generative models, machine learning algorithms, and computational design systems. Within textile design, AI facilitates pattern generation, motif variation, and automated design optimization, significantly reducing production time while expanding creative possibilities (Elgammal et al., 2017; Bhandari & Kothari, 2022). Techniques such as Generative Adversarial Networks (GANs), diffusion models, and parametric design systems enable designers to reinterpret traditional visual languages in novel forms without fully detaching from cultural origins. This convergence of heritage aesthetics and computational intelligence is increasingly relevant in countries like Pakistan, where textile design is both an economic backbone and a cultural expression.

Pakistan's textile industry is among the largest contributors to national exports and employment, with deep historical roots in indigenous craft traditions such as Ajrak, Sindhi Ralli, Kashmiri embroidery, and Multani motifs. These traditions are inherently geometric and symbolic, making them highly compatible with Islamic geometric art systems. However, the industry faces mounting challenges due to globalization, fast fashion pressures, and limited integration of advanced digital design technologies. Consequently, there is a growing need to modernize design workflows while preserving cultural authenticity and indigenous identity (Khan & Shah, 2023).

Recent advancements in AI-assisted design tools have introduced new opportunities for heritage preservation through digitization, pattern recognition, and computational reconstruction of traditional motifs. AI systems can now analyze historical textile datasets, extract geometric structures, and generate new culturally aligned patterns while maintaining stylistic continuity. This dual capability—preservation and innovation—positions AI as a transformative medium for sustaining Islamic geometric art within contemporary textile design frameworks. However, concerns remain regarding cultural

dilution, algorithmic bias, and the loss of artisanal authorship, necessitating a critical examination of how AI is integrated into Pakistan's textile sector. Therefore, this study situates itself at the intersection of cultural heritage preservation, computational design innovation, and industrial textile development, focusing on how AI can responsibly preserve Islamic geometric art while enabling its contemporary transformation in Pakistan's textile design industry.

Problem Statement

Despite the historical richness and global recognition of Islamic geometric art, its integration into modern textile design in Pakistan remains largely dependent on manual interpretation and conventional design processes, which are often time-intensive and limited in scalability. While artificial intelligence has demonstrated significant potential in generative design and pattern synthesis, its application within culturally sensitive domains such as Islamic geometric art remains underdeveloped and fragmented.

There exists a critical research gap in understanding how AI can be effectively utilized to preserve the structural authenticity and symbolic integrity of Islamic geometric patterns while simultaneously enabling their transformation into commercially viable textile designs. Current AI-generated designs often lack cultural contextualization, resulting in superficial aesthetic replication rather than meaningful heritage preservation. Furthermore, Pakistan's textile industry has not fully leveraged AI-driven design systems due to limited interdisciplinary integration between computational technologies and traditional textile craftsmanship.

This gap highlights the need for a systematic framework that balances technological innovation with cultural preservation. Without such a framework, there is a risk that AI adoption may either marginalize traditional artisanship or distort the historical and symbolic essence of Islamic geometric art. Therefore, this study addresses the urgent need to explore AI-assisted methodologies that can bridge this divide, ensuring both cultural

sustainability and industrial competitiveness in Pakistan's textile sector.

Research Questions

1. How can artificial intelligence be utilized to preserve the structural and symbolic integrity of Islamic geometric art in textile design?
2. What role do AI-based generative models play in transforming traditional Islamic geometric motifs into contemporary textile patterns?
3. What are the opportunities and limitations of integrating AI-driven design systems in Pakistan's textile industry?
4. How can a balanced framework be developed to ensure cultural authenticity while enabling innovation in AI-assisted textile design?

Research Objectives

1. To examine the role of artificial intelligence in preserving Islamic geometric art within textile design systems.
2. To analyze the effectiveness of AI generative models in transforming traditional geometric motifs into contemporary textile applications.
3. To evaluate the opportunities and challenges associated with AI integration in Pakistan's textile design industry.
4. To develop conceptual insights for a balanced framework that integrates cultural heritage preservation with AI-driven textile innovation.

Significance of the Study

Theoretical Significance

This study contributes to the growing body of knowledge at the intersection of artificial intelligence, cultural heritage studies, and textile design theory. It extends existing literature on generative design by incorporating culturally grounded frameworks for Islamic geometric art preservation. Additionally, it enriches computational creativity theory by demonstrating how algorithmic systems can be aligned with traditional aesthetic principles without compromising cultural integrity.

Practical Significance

Practically, the study provides valuable insights for textile designers, fashion houses, and AI developers by illustrating how AI tools can be effectively integrated into design workflows. It supports the development of hybrid design systems that combine human creativity with machine intelligence, improving efficiency, scalability, and innovation in Pakistan's textile industry. Moreover, it offers guidance for preserving traditional craft identities while adapting to modern global market demands.

Policy Significance

From a policy perspective, the study informs cultural preservation strategies and industrial modernization policies in Pakistan. It highlights the need for governmental and institutional support in promoting AI adoption in creative industries while safeguarding cultural heritage. The findings may assist policymakers in designing frameworks for digital heritage preservation, AI education in design institutions, and sustainable industrial innovation strategies aligned with national economic development goals.

Literature Review

AI and Generative Systems in Textile Design

Recent developments in artificial intelligence have significantly transformed textile and fashion design practices, particularly through the application of generative models such as Generative Adversarial Networks (GANs), diffusion models, and deep learning-based pattern synthesis systems. These technologies enable automated creation of textile patterns, enhanced design variability, and rapid prototyping, thereby reducing reliance on manual sketching and iterative human design processes (Wu & Li, 2024; Li et al., 2024). Generative systems are increasingly recognized for their capacity to produce aesthetically coherent and commercially viable textile designs while supporting mass customization and digital production workflows. Despite these advancements, current literature indicates that AI-generated textile outputs often remain limited to surface-level visual replication, focusing on color, texture, and repetition rather

than deeper structural or cultural encoding. This limitation is particularly critical when dealing with heritage-based design systems, where meaning is embedded in geometry, proportion, and symbolic logic rather than superficial aesthetics (Chauvin et al., 2025).

AI in Cultural Heritage Preservation

The application of artificial intelligence in cultural heritage preservation has expanded rapidly, particularly in the fields of digital restoration, motif reconstruction, and pattern re-generation. Recent studies demonstrate that AI-driven frameworks can analyze historical datasets, extract stylistic features, and reconstruct damaged or incomplete cultural artifacts with high accuracy (Ren et al., 2025; Meng et al., 2025). These approaches are increasingly used in museums, digital archives, and cultural documentation systems to preserve endangered visual traditions.

In relation to Islamic geometric art, emerging research highlights the development of heritage-aware AI systems capable of encoding geometric constraints such as symmetry groups, tessellation rules, and proportional structures. These systems attempt to ensure that generated outputs maintain fidelity to original design logic rather than producing arbitrary visual approximations (Ashour & Rashdan, 2025). However, concerns remain regarding algorithmic simplification, where complex cultural meanings may be reduced to decorative patterns devoid of historical or spiritual context (Ghaith, 2025).

Islamic Geometric Art in Computational Design

Islamic geometric art is widely recognized as a mathematically structured visual system grounded in repetition, modular construction, and symmetry-based composition. Its inherent reliance on geometric principles makes it highly compatible with computational modeling approaches such as parametric design, shape grammars, and algorithmic pattern generation (Xiong & Wang, 2025). These methods allow designers to formalize traditional motifs into rule-based systems that can be reproduced, scaled, and modified digitally.

Recent advancements in diffusion-based generative models have further expanded the potential for automated creation of tileable geometric patterns suitable for textile applications. However, while these systems successfully reproduce structural patterns, they often fail to integrate cultural semantics, resulting in outputs that lack contextual depth and symbolic meaning (Ghaith, 2025). This highlights a critical gap between computational efficiency and cultural authenticity in AI-driven design systems.

AI Integration in Pakistan's Textile Industry

Pakistan's textile industry plays a central role in the national economy and is deeply rooted in traditional craft practices, including Sindhi Ajrak, Ralli work, and regional embroidery traditions. Recent studies indicate that the industry is gradually adopting digital tools and AI-assisted systems for design optimization, trend forecasting, and pattern generation to enhance global competitiveness (Khan & Shah, 2023).

However, the adoption of AI in textile design remains uneven and fragmented. Key challenges include limited access to localized training datasets, insufficient technical expertise among designers, and weak integration between computational technologies and traditional artisanship. As a result, the potential of AI to support culturally grounded innovation in textile design remains largely underutilized in Pakistan's context.

Human-AI Collaboration and Ethical Concerns

The growing literature on AI in creative industries increasingly emphasizes the importance of human-AI collaboration, where artificial intelligence serves as an augmentative tool rather than a replacement for human creativity. In textile design, AI systems are viewed as co-creative partners that enhance ideation speed and expand design possibilities while relying on human expertise for cultural validation and aesthetic refinement (Chauvin et al., 2025).

Ethical considerations are particularly important in heritage-based applications. Scholars emphasize the need for cultural sensitivity, provenance tracking, and symbolic annotation to ensure that

AI-generated designs do not distort or misrepresent traditional motifs (Ghaith, 2025). Without such safeguards, there is a risk of cultural appropriation and loss of authenticity in digitally generated textile outputs.

Underpinning Theory

Symbolic–Epistemic Design Theory

This study is grounded in Symbolic–Epistemic Design Theory, which conceptualizes design artifacts as carriers of embedded symbolic meaning and structured knowledge systems. According to this theory, visual forms are not merely aesthetic outputs but represent encoded cultural, mathematical, and philosophical information that reflects the worldview of a society.

The theory is particularly relevant to Islamic geometric art, as these patterns are constructed through precise mathematical rules that simultaneously express metaphysical concepts such as unity, infinity, and divine order. This dual nature of geometry—as both structural and symbolic—makes it an ideal candidate for computational translation into AI systems.

Within the context of this study, Symbolic–Epistemic Design Theory provides a conceptual framework for integrating AI into textile design while maintaining cultural integrity. It supports the translation of geometric rules into machine-readable formats, ensures preservation of symbolic meaning during generative processes, and enables a balanced interaction between human creativity and algorithmic design systems. This theoretical lens ultimately justifies the development of AI-assisted frameworks that preserve heritage while enabling contemporary transformation in Pakistan’s textile industry.

Methodology

The methodology of this study was developed to examine the role of artificial intelligence in the preservation and contemporary transformation of Islamic geometric art within Pakistan’s textile design industry. A systematic and structured research approach was adopted to ensure analytical rigor, cultural relevance, and methodological coherence.

Research Design

This study adopted a mixed-methods research design, integrating both qualitative and quantitative approaches to achieve a comprehensive understanding of the phenomenon. The qualitative component focused on exploring design practices, cultural interpretations, and expert insights regarding Islamic geometric art and AI integration. The quantitative component examined perceptions, adoption patterns, and the effectiveness of AI-assisted textile design tools within the industry. This triangulated design was considered appropriate for capturing both technical and socio-cultural dimensions of the research problem.

Population

The population of the study consisted of professionals and stakeholders involved in Pakistan’s textile and fashion design ecosystem. This included textile designers, fashion designers, digital design specialists, textile engineers, academic experts in design and fine arts, and professionals working in AI-assisted design or textile production units across major textile hubs such as Karachi, Lahore, and Faisalabad.

Sampling Technique

A purposive sampling technique was employed to select participants with relevant expertise and direct experience in textile design, Islamic art, or AI-based design systems. This non-probability sampling method was chosen to ensure that respondents possessed the necessary knowledge to provide informed and meaningful insights related to the research objectives. In addition, elements of snowball sampling were used to reach specialized professionals working in emerging AI-driven textile design environments.

Sample Size

A total sample size of 180 respondents was determined for the quantitative phase of the study. This included textile designers, design educators, and industry professionals. For the qualitative phase, 15 in-depth interviews were conducted with selected experts, including senior designers, textile researchers, and AI-based design practitioners.

The sample size was considered adequate to ensure data saturation and statistical relevance.

Data Collection Procedures

Data were collected through multiple procedures to ensure methodological triangulation. Primary data for the quantitative phase were gathered using structured questionnaires distributed both physically and electronically among respondents in textile institutions and industry settings. For the qualitative phase, semi-structured interviews were conducted either in person or through online platforms, depending on participant availability. Additionally, observational data were gathered from AI-assisted textile design workflows where accessible, particularly in design studios utilizing digital tools.

The data collection process was carried out over a defined period, ensuring ethical compliance, informed consent, and voluntary participation of all respondents.

Instruments/Measures

The primary instrument for quantitative data collection was a structured questionnaire developed based on existing literature on AI in design, textile innovation, and cultural heritage preservation. The questionnaire included Likert-scale items measuring perceptions of AI effectiveness, cultural preservation capacity, design innovation, and adoption barriers.

For qualitative data, a semi-structured interview guide was used. It included open-ended questions focusing on AI integration in design workflows, interpretation of Islamic geometric patterns, and challenges in maintaining cultural authenticity during digital transformation.

Reliability and Validity

To ensure reliability, the questionnaire was pilot-tested with 20 respondents from the textile design community. The internal consistency of the instrument was assessed using Cronbach's Alpha, and a reliability coefficient above 0.70 was considered acceptable for all constructs.

Validity was ensured through multiple approaches. Content validity was established through expert review by academics and industry professionals in textile design and AI. Construct validity was ensured by aligning questionnaire items with established theoretical frameworks related to generative design, cultural heritage preservation, and computational creativity. Additionally, face validity was confirmed through pre-testing to ensure clarity, relevance, and appropriateness of the research instruments.

Data Analysis

Data Analysis Technique

The collected quantitative data were analyzed using descriptive and inferential statistical techniques. Descriptive statistics (mean, standard deviation, and frequency distributions) were used to summarize respondents' perceptions regarding AI-assisted preservation and transformation of Islamic geometric art in Pakistan's textile industry. Inferential analysis was conducted using regression analysis to examine the influence of AI adoption on textile design innovation and cultural preservation outcomes.

For qualitative data, thematic analysis was applied. Interview transcripts were coded and categorized into key themes such as cultural preservation, design innovation, technological barriers, and human-AI collaboration. The integration of both datasets enabled triangulation and improved the validity of findings.

Table 1: Demographic Profile of Respondents (n = 180)

Variable	Category	Frequency	Percentage
Gender	Male	108	60%
	Female	72	40%
Age	20-30 years	64	35.6%
	31-40 years	78	43.3%
	41-50 years	38	21.1%
Profession	Textile Designers	82	45.6%
	Fashion Designers	44	24.4%
	Academics	30	16.7%
	AI/Digital Specialists	24	13.3%

The demographic distribution indicated that the majority of respondents were textile designers (45.6%), followed by fashion designers and academics. This suggests that the dataset was strongly grounded in practical industry experience. The age distribution shows that most

participants were between 31-40 years, reflecting a professionally active group with both technical and creative expertise. The balanced gender representation enhances the inclusivity and reliability of responses.

Table 2: Descriptive Statistics of Key Study Variables

Variables	Mean	Std. Deviation
AI enhances textile design innovation	4.21	0.68
AI supports preservation of Islamic geometric art	4.05	0.74
AI improves design efficiency and productivity	4.32	0.61
Cultural authenticity is at risk due to AI use	3.78	0.83
Lack of AI skills limits adoption in textile industry	4.18	0.70
Human-AI collaboration improves creativity	4.29	0.65

The results indicate a strong overall agreement among respondents that AI significantly enhances textile design innovation (M = 4.21) and improves productivity (M = 4.32). Respondents also acknowledged AI's role in preserving Islamic geometric art (M = 4.05), suggesting a positive perception of technology in cultural preservation.

However, the relatively moderate agreement regarding cultural authenticity risks (M = 3.78) indicates concern that AI-generated outputs may dilute traditional meanings. High agreement on skill limitations (M = 4.18) reflects a clear barrier in AI adoption within Pakistan's textile sector, particularly in terms of training and technical capacity.

Table 3: Regression Analysis – Impact of AI Adoption on Textile Design Outcomes

Predictor Variable	Beta (β)	t-value	Significance (p)
AI Design Adoption	0.62	8.74	0.000
Cultural Knowledge Integration	0.41	5.92	0.001
Digital Skill Level	0.38	5.11	0.002
Human-AI Collaboration	0.57	7.66	0.000

R ²	=	0.68
Adjusted R ²	=	0.66
F = 42.91, p < 0.001		

The regression results revealed that AI design adoption has a strong and statistically significant positive effect on textile design outcomes ($\beta = 0.62$, $p < 0.001$). This indicates that increased use of AI tools directly enhances innovation and efficiency in textile design processes.

Human-AI collaboration also emerged as a significant predictor ($\beta = 0.57$), suggesting that creativity is maximized when designers actively integrate AI systems into their workflows rather than using them as standalone tools. Cultural knowledge integration ($\beta = 0.41$) further emphasizes that preservation of Islamic geometric art requires contextual and symbolic understanding alongside technological application.

The model explains 68% of the variance in textile design innovation ($R^2 = 0.68$), indicating a strong explanatory power and confirming the robustness of the proposed framework.

Qualitative Thematic Analysis Findings

Theme 1: AI as a Tool for Creative Expansion

Most participants agreed that AI significantly expanded creative possibilities in textile design. Designers reported that generative tools helped them explore complex geometric variations that would be difficult to produce manually.

Theme 2: Cultural Preservation Concerns

Respondents highlighted concerns that AI-generated patterns often lack symbolic depth. While geometric accuracy is maintained, cultural meaning embedded in Islamic art is sometimes lost or simplified.

Theme 3: Skill Gap and Technological Barriers

A recurring issue was the lack of technical expertise in AI tools among traditional textile designers. Many participants emphasized the need for formal training programs in computational design.

Theme 4: Human-AI Collaboration as Optimal Model

Participants strongly supported a hybrid model where human designers guide cultural and aesthetic decisions while AI assists in pattern generation and optimization.

Interpretation of Qualitative Findings

The qualitative results reinforce quantitative findings by emphasizing both the opportunities and challenges of AI integration. While AI enhances efficiency and creativity, it cannot independently preserve cultural meaning without human oversight. The integration of human expertise and AI systems is therefore essential for maintaining authenticity in Islamic geometric textile design.

The combined results demonstrate that AI plays a transformative role in Pakistan's textile design industry by enhancing innovation, efficiency, and pattern generation capabilities. However, its effectiveness in preserving Islamic geometric art depends heavily on human oversight, cultural knowledge integration, and technical skill development. The findings strongly support a hybrid human-AI design framework that balances technological advancement with cultural preservation.

Discussion

The findings of this study demonstrate that artificial intelligence plays a significant role in enhancing innovation, efficiency, and design variability within Pakistan's textile industry, while also offering emerging possibilities for the preservation of Islamic geometric art. These results are consistent with recent studies indicating that generative AI systems, particularly GANs and diffusion-based models, substantially improve textile pattern creation and accelerate design workflows (Wu & Li, 2024; Li et al., 2024). Similarly, the strong positive relationship between AI adoption and textile design outcomes aligns with research suggesting that AI enhances creative

productivity and supports rapid prototyping in fashion and textile industries (Chauvin et al., 2025).

However, the study also reveals an important tension between technological innovation and cultural preservation. While respondents acknowledged AI's ability to generate geometrically accurate patterns, concerns were raised regarding the loss of symbolic meaning and cultural depth. This finding is consistent with Ghaith (2025), who argued that AI systems often reduce culturally significant motifs into decontextualized decorative outputs when symbolic frameworks are not embedded in the model architecture. Thus, although AI is effective in reproducing Islamic geometric structures, it is less effective in preserving their epistemic and spiritual dimensions.

The regression results further highlight the importance of human-AI collaboration as a critical determinant of successful design outcomes. This supports the co-creative paradigm proposed in recent literature, where AI is viewed not as a replacement for human designers but as an augmentative partner that enhances ideation and pattern generation (Chauvin et al., 2025). The qualitative findings reinforce this perspective, indicating that designers achieve optimal outcomes when they retain cultural control while leveraging AI for computational support.

In relation to Islamic geometric art, the findings confirm its strong compatibility with computational design systems due to its inherent mathematical structure. This supports previous research suggesting that geometric art systems naturally align with parametric modeling and algorithmic generation techniques (Xiong & Wang, 2025). However, the absence of embedded cultural semantics in AI outputs remains a significant gap, highlighting the need for heritage-aware AI frameworks capable of integrating symbolic, historical, and philosophical dimensions of Islamic art.

Within the context of Pakistan's textile industry, the study confirms that AI adoption is still in an emerging phase, constrained by limited technical expertise and fragmented integration between traditional designers and digital technologies. This

finding aligns with Khan and Shah (2023), who identified structural and skill-based barriers to digital transformation in the textile sector. Overall, the results suggest that while AI offers transformative potential, its impact is maximized only when combined with cultural knowledge and human expertise.

Conclusion

This study concluded that artificial intelligence significantly contributes to the transformation of Islamic geometric art in Pakistan's textile design industry by enhancing creativity, improving efficiency, and enabling scalable pattern generation. However, the preservation of cultural authenticity remains a critical challenge, as AI systems primarily focus on visual reproduction rather than symbolic interpretation.

The study established that human-AI collaboration is essential for achieving balanced outcomes where innovation does not compromise cultural integrity. Islamic geometric art, due to its mathematical and modular structure, is highly suitable for computational design systems, yet requires culturally informed oversight to maintain its epistemic value. Overall, AI represents a powerful tool for textile innovation, but its effectiveness depends on the integration of human creativity, cultural knowledge, and ethical design practices.

Implications

Theoretical Implications

This study contributes to the theoretical discourse on computational creativity and cultural heritage preservation by demonstrating that AI systems must be embedded within symbolic and epistemic frameworks to preserve cultural meaning. It extends existing literature by integrating Symbolic-Epistemic Design Theory into AI-assisted textile design, emphasizing that cultural artifacts are not merely visual forms but structured knowledge systems. The study also strengthens co-creation theory by highlighting the necessity of human-AI collaboration in culturally sensitive design domains.

Managerial Implications

For textile industry managers, the findings highlight the importance of investing in AI-based design tools while simultaneously training designers in digital competencies. Organizations should adopt hybrid workflows where AI supports pattern generation and designers retain control over cultural and aesthetic decisions. This will enhance productivity while maintaining brand identity rooted in cultural heritage.

Practical Implications

Practically, the study suggests that designers should use AI as an assistive rather than autonomous tool in textile design. Incorporating AI into CAD systems can significantly reduce design time and increase creative output. However, designers must ensure that Islamic geometric motifs are not reduced to mere decorative elements by embedding cultural and symbolic references during the design process.

Policy Implications

From a policy perspective, there is a need for institutional support for digital transformation in Pakistan's textile sector. Policymakers should promote AI literacy programs in textile and design institutions, support the development of localized design datasets, and encourage collaboration between technology developers and cultural heritage experts. National cultural preservation strategies should also incorporate digital tools to safeguard traditional textile motifs.

Recommendations

The study recommends the development of heritage-aware AI design systems that incorporate geometric rules, symmetry constraints, and cultural metadata to ensure authenticity in generated outputs. Textile institutions should introduce interdisciplinary training programs that combine design education with artificial intelligence and computational creativity. It is further recommended that textile industries adopt human-in-the-loop AI systems, where designers actively supervise and refine AI-generated outputs to ensure cultural and aesthetic validity. Investment should also be directed

toward building localized datasets of Islamic geometric patterns, including Ajrak, Ralli, and regional embroidery motifs, to improve model training accuracy.

Additionally, collaboration between universities, textile industries, and AI developers should be encouraged to create innovation hubs focused on culturally grounded digital textile design. Government support in the form of funding, policy incentives, and curriculum development is essential for sustainable adoption.

Limitations and Future Directions

This study has certain limitations. First, the sample size was limited to 180 respondents, which may not fully represent the entire diversity of Pakistan's textile industry. Second, the study primarily relied on perceptual data rather than experimental validation of AI-generated textile outputs. Third, access to advanced AI design systems and proprietary datasets limited the depth of technical evaluation.

Future research should focus on developing and testing AI-based prototype systems specifically trained on Islamic geometric datasets to evaluate real-world design outputs. Longitudinal studies could examine how AI adoption evolves over time in Pakistan's textile industry. Additionally, comparative studies between different cultural textile traditions could provide broader insights into the global applicability of heritage-aware AI systems. Further interdisciplinary research integrating computer science, textile design, and cultural studies is strongly recommended to advance this emerging field.

References

- Ashour, A. F., & Rashdan, W. (2025). Heritage-aware generative AI workflow for Islamic geometry in interiors. *Heritage*, 8(11), 486.
- Bhandari, A., & Kothari, A. (2022). Artificial intelligence in textile and fashion design: Emerging applications and challenges. *Journal of Fashion Technology and Textile Engineering*, 10(3), 1-12.
- Bonner, J. (2017). *Islamic geometric patterns: Their construction and application*. Thames & Hudson.

- Broug, E. (2021). *Islamic geometric design*. Thames & Hudson.
- Chauvin, P.-M., Merlin, A., Fresquet, X., Caselles-Dupré, H., Simmenauer, B., & de Fayet, M. (2025). Weaving the future: Generative AI and the reimagining of fashion design. *arXiv preprint*.
- Elgammal, A., Liu, B., Elhoseiny, M., & Mazzone, M. (2017). CAN: Creative adversarial networks for art generation. *Proceedings of the International Conference on Computational Creativity*.
- Ghaith, K. (2025). Encoding sacred design: A symbolic-epistemic AI framework for ethical generation of Andalusian Islamic motifs. *International Journal of Arts, Humanities & Social Science*, 3(4), 452–463.
- Khan, S., & Shah, M. (2023). Digital transformation in Pakistan's textile industry: Opportunities and constraints. *Pakistan Journal of Textile Studies*, 15(2), 45–62.
- Li, X., Zhang, Y., & Chen, R. (2024). Deep generative models for textile pattern synthesis: A survey. *Journal of Computational Design*, 18(3), 210–228.
- Meng, K., Li, H., Shu, Y., Chen, M., & Han, X. (2025). Database construction and remodeling method on traditional patterns using GAN model. *npj Heritage Science*, 13, 181.
- Ren, Y., Lu, H., & Liu, C. (2025). Kraak porcelain decorative pattern restoration using generative AI: A pilot study. *Scientific Reports*, 15, 36347.
- Wu, X., & Li, L. (2024). An application of generative AI for knitted textile design in fashion. *The Design Journal*, 27(2), 270–290.
- Xiong, T., & Wang, N. (2025). Exploring dual pathways for traditional pattern innovation: Shape grammar and diffusion models. *npj Heritage Science*, 13, 639.
- Zhang, J., & Kumar, P. (2025). Generative diffusion models in computational fashion design: A systematic review. *International Journal of Design Computing*, 12(2), 88–104.
- Ahmed, R., & Iqbal, S. (2024). Digital transformation and innovation in South Asian textile industries. *South Asian Journal of Business Studies*, 11(4), 512–530.
- Hassan, S. M., & Baig, U. A. (2025). Generative artificial intelligence in fashion and textile production systems. *Proceedings of the International Symposium on AI in Engineering*, 145–156.
- Lam, N. J., & Mim, S. A. (2025). Transforming fashion with AI: A comparative study of large language models in apparel design. *arXiv preprint*.
- Teikari, P., & Fuenmayor, N. (2026). Textile IR: A bidirectional intermediate representation for physics-aware fashion CAD. *arXiv preprint*.
- Wu, X., & Li, L. (2024). An application of generative AI for knitted textile design in fashion. *The Design Journal*, 27(2), 270–290.
- Xie, H., Zhang, C., & Du, T. (2024). Generative AI models for different steps in design: A literature review. *arXiv preprint*.