A Critical Analysis of the Reliability of Generative Models in Preserving Cultural Privacy: Towards Sustainable Digital Fashion Design Using Artificial Intelligence

Suad Abdullah AlGhamdi
University of Bisha, Bisha, Kingdom of Saudi Arabia
Email: sateh@ub.edu.sa, salghamdi1803@stu.kau.edu.sa

Nermeen Abdelrahman Abdelbaset Mohamed
King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia
Email: naamohamad@kau.edu.sa

Abstract
This study aims to analyze the reliability of generative AI models in representing cultural privacy within the field of digital fashion design. A generative model was developed using a curated Saudi heritage database and tested on over fifty generated designs. The study adopted an applied evaluative methodology using an integrated toolset: a technical assessment by experts and a visual questionnaire for designers and specialists. Results indicated that identity-informed designs significantly outperformed non-informed ones in terms of cultural representation, attractiveness, wearability, and clarity of inspiration. Findings also confirmed that integrating heritage data substantially enhances the quality of visual outputs. The study presents a practical model for embedding cultural sensitivity into design algorithms and recommends the adoption of this methodology in other cultural contexts.
Keywords: Generative Models, Cultural Privacy, Sustainable Digital Fashion, Artificial Intelligence

Introduction
Artificial intelligence (AI) is rapidly transforming creative industries worldwide, with digital fashion design emerging as a prominent field of innovation. Generative AI models now possess the remarkable ability to create complex and original visual designs, offering unprecedented opportunities for designers and brands (Goodfellow et al., 2020; Ramesh et al., 2022). Despite this progress, a critical gap remains in ensuring these models effectively capture and honor cultural identities, especially within fashion—a domain deeply intertwined

with history, tradition, and social meaning (Hall, 1997). Without proper cultural sensitivity, AI-generated designs risk producing superficial or inaccurate representations that undermine the rich symbolism embedded in traditional attire.

The importance of studying this topic stems from the growing global interest in preserving cultural heritage while leveraging modern technology for creative expression. In Saudi Arabia, this balance is of particular significance due to Vision 2030, which explicitly calls for the promotion of creative industries that are firmly rooted in Saudi heritage and identity. Integrating AI technologies in a way that respects cultural nuances is essential to supporting this national agenda and enabling designers to innovate responsibly.

This study is vital because it explores how generative AI models, when trained on carefully curated cultural data specific to Saudi Arabia, can serve as effective tools for producing digital fashion designs that authentically reflect and preserve local heritage. The research aims to bridge the divide between advanced technology and cultural authenticity, ensuring that AI not only enhances creativity but also safeguards identity.

The practical utility of this research extends to multiple stakeholders. Fashion designers and creative industries in Saudi Arabia can benefit from AI-driven tools that empower them to incorporate heritage elements accurately and innovatively. Cultural institutions and policymakers gain a framework for evaluating and guiding AI applications in heritage-sensitive domains. Moreover, consumers and society at large stand to benefit from digital designs that reinforce cultural pride and awareness in an increasingly digital world.

Ultimately, this study contributes a methodological approach for assessing the cultural reliability of AI-generated fashion visuals and demonstrates the potential for generative techniques to promote sustainable, identity-respecting creativity. By addressing this intersection of AI, culture, and design, the research advances knowledge on how emerging technologies can be harnessed to support cultural preservation and creative innovation in a responsible and meaningful way.

Theoretical Framework and Literature Review
Generative AI models are among the most notable achievements of the recent technological revolution. These models rely on algorithms capable of generating new content that resembles the original data they were trained on (Brown et al., 2020). Prominent examples include DALL·E, Midjourney, and Stable Diffusion, all of which have demonstrated high efficacy in producing detailed visual designs.

Despite these technological advances, several studies have shown that generative models often exhibit cultural bias when trained on non-specialized data (Birhane & Prabhu, 2021), resulting in inaccurate or stereotypical designs. Lee & Kim (2022) pointed out that generative models can reflect local specificities only when supplied with culturally guided training data and that model effectiveness hinges on the accuracy and quality of input data. Zhang et al. (2023) emphasized the importance of crafting culturally meaningful prompts to generate symbolically and architecturally accurate outputs.

On another front, studies in cultural sociology (Hall, 1997; Said, 1978) argue that identity is not a fixed essence but a social-symbolic construct that must be handled cautiously when visually represented. These frameworks warn against reducing culture to mere patterns or costumes without understanding its historical, political, and symbolic contexts.

In the Arab region, studies evaluating AI's capacity to represent cultural identity remain scarce. However, some recent research, such as AlGhamdi (2023), has underscored the importance of directing AI to serve heritage, stressing the need for involving cultural experts in model development.

This study addresses a critical research gap by combining the use of a generative model (GPT-4 + DALL·E) trained with Saudi heritage data and a detailed analysis of design outputs using specialized evaluation tools—thereby making an original contribution to both AI and cultural studies.

Study Objectives and Research Questions
The study aims to achieve the following objectives:
1. Test the ability of generative models supported by cultural data to produce designs that reflect Saudi cultural specificity.
2. Evaluate the differences between identity-informed and non-informed designs in terms of cultural representation, visual appeal, wearability, and clarity of inspiration.
3. Propose a practical framework for incorporating cultural sensitivity into generative models used in digital fashion design.
   The study seeks to answer the following research questions:
1. To what extent do identity-informed designs accurately represent Saudi cultural identity compared to non-informed designs?
2. Are there statistically significant differences in expert evaluations of the designs across the four assessment dimensions?
3. How effective are culturally trained generative models as tools for designing sustainable digital fashion that respects cultural identity?

Study Variables
The study was structured around a precise set of variables for evaluation and analysis. The independent variable was the type of design produced by the generative AI model, categorized into identity-informed and non-informed outputs. The dependent variables were based on four primary evaluation dimensions: representation of cultural identity, visual appeal, wearability, and clarity of cultural inspiration, as assessed by domain experts.
Additionally, the study examined qualitative secondary variables, including symbolic and cultural impressions associated with the outputs and the perceived effectiveness of the culturally trained model in generating designs that reflect Saudi uniqueness. The study also aimed to propose a practical framework that embeds cultural sensitivity into generative design mechanisms, as illustrated in the conceptual model (Figure 1).
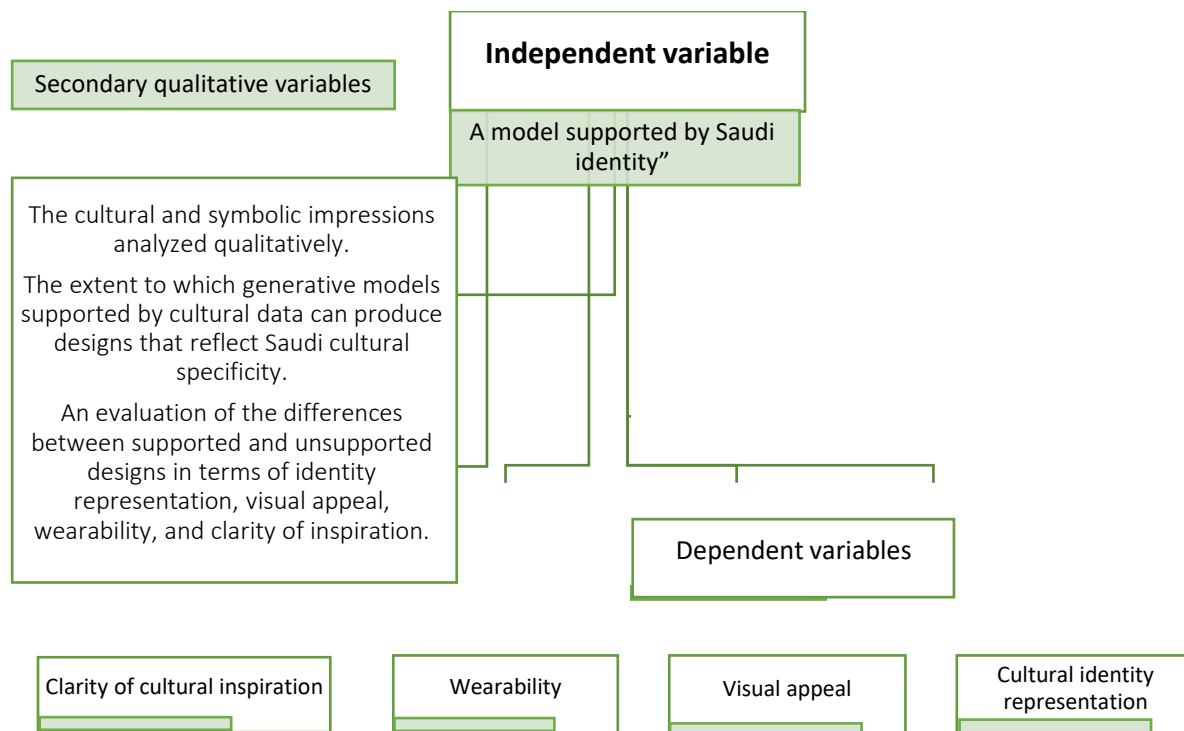
Figure (1): The conceptual framework of the main variables in the study

Significance of Study

This study holds critical significance at the convergence of three key strategic areas: rapid advancements in artificial intelligence (AI) technologies, the ongoing shift towards digital and generative design in creative industries, and the urgent need to preserve and promote cultural identity within an increasingly globalized visual landscape. As generative AI models become integral to creative workflows, it is essential to evaluate their capacity to authentically represent cultural symbols and generate outputs that embody accurate, locally meaningful designs. This ensures these technologies contribute positively rather than dilute or misrepresent cultural heritage.

The practical utility of this research is multifaceted. For fashion designers, creative professionals, and cultural entrepreneurs in Saudi Arabia, the study offers insights and tools to leverage AI for innovation that aligns with heritage preservation, enabling them to create designs that resonate with national identity while appealing to global markets. Cultural policymakers and institutions will find value in the framework and findings, which support informed decision-making to foster culturally sensitive AI applications in creative sectors. Additionally, technology developers and AI practitioners can use the study's roadmap to design more responsible, ethical, and culturally-aware generative models, thus advancing AI fairness and inclusivity.

Aligned with the objectives of Saudi Vision 2030, this study reinforces the Kingdom's commitment to nurturing cultural industries, with fashion as a pivotal pillar of the creative economy. By ensuring that AI technologies serve to amplify rather than overshadow cultural narratives, the study contributes directly to national strategies aimed at embedding cultural identity into digital innovation.

From an academic perspective, this research addresses a significant gap in Arabic-language scholarship concerning the integration of cultural specificity within generative AI. Currently, there is limited empirical evidence on how such models can be trained and evaluated to produce culturally representative and ethically sustainable designs. The study's outcomes provide a critical assessment of model reliability in this context and propose a replicable methodological framework that can be adapted for other cultural settings and creative fields. In summary, this study is important not only for advancing theoretical knowledge but also for its real-world applicability. It guides stakeholders across creative industries, technology development, cultural policy, and academia in harnessing AI's potential responsibly—promoting sustainable, culturally rich digital creativity that benefits both local communities and the broader global audience.

Study Scope, Sample, and Justifications
Scope of the Study:
- Thematic Scope: The study focuses on assessing the capacity of generative AI models to represent cultural specificity through digital fashion designs. It does not extend to other fields such as music or architecture.
- Geographical Scope: The study is limited to the Saudi cultural identity as an application domain, focusing on diverse regions such as Najd, Hijaz, the South, and the North.
- Temporal Scope: The study was conducted from October 2023 to March 2024.
- Human Scope: Participants included:
    - (15) experts in digital fashion and cultural identity who evaluated 50 generated designs.
    - (40) Saudi fashion specialists (30 Saudi designers + 10 cultural identity experts) who participated in a specialized visual survey.
- Technical Scope: GPT-4 with DALL·E was used to generate designs based on culturally guided inputs.

Justification for Sample Selection
A purposive sample was selected due to the specialized nature of the study, which required the participation of experts and designers with deep knowledge of local heritage and culture, as well as the ability to evaluate visual outputs with accurate cultural references. This type of sample is appropriate for qualitative evaluative research that prioritizes the quality of analysis over statistical generalization.

Methodology and Model Design
The study adopted an applied evaluative approach carried out in two sequential phases, with this paper representing the first phase. In this phase, a generative model was built and trained using GPT-4 integrated with DALL·E, fed with structured Saudi cultural data. The objective was to test the model's readiness to produce culturally localized digital designs. Outputs from this phase were evaluated by experts to ensure the model's effectiveness before proceeding to the next phase, which will involve real-use testing by designers.

Methodologically, the study used a mixed-methods approach, combining qualitative generative analysis of cultural connotations in the designs with quantitative statistical analysis of assessment tools and survey results. Elements of a quasi-experimental approach were also

employed to develop a preliminary tool used to evaluate model outputs across nine main criteria. This evaluation aimed to assess the initial readiness of the model before broader implementation in the second phase.

The expert evaluation tool formed the first step in verifying model effectiveness. It was used by 15 experts in digital fashion and heritage to assess 50 generated designs. A visual questionnaire was then developed and distributed to 40 fashion designers and cultural identity specialists to assess the representation of identity in the designs across four additional criteria. Data were analyzed using means, standard deviations, and Chi-square tests, alongside open qualitative analysis of symbolic and cultural observations related to the designs.

Model Development Phases
1. Phase One: Collecting and classifying cultural data from reliable sources, including identity elements and symbols such as clothing styles, motifs, fabrics, colors, and traditional architectural elements.
2. Phase Two: Creating culturally reflective descriptive prompts for the model that visually represent Saudi identity.
3. Phase Three: Generating preliminary designs using GPT-4 + DALL·E.
4. Phase Four: Conducting internal review of the designs to ensure accurate visual representation.

To validate generation quality, the following figures illustrate comparisons between identity-supported and non-supported AI-generated designs, based on specific cultural sources of inspiration.

Tabel 1
A comparison between the cultural reference and an AI-supported versus non-supported design of the Najdi bisht.

Item	Original (Cultural Reference)	AI-Generated Image (fed)	AI-Generated Image (Non Fed)
DI	**Inspiration Source**	Design A	Design B
Descript ion of Cultural	The Burqa of Al-Burqa is made from hand-spun goat wool, open at the front, wide in width and		

Item	Original (Cultural Reference)	AI-Generated Image (fed)	AI-Generated Image (Non Fed)
Reference	sleeves, featuring long broad stripes in white and black or brown separated by a thin white line. It is worn during winter.		
Prompt Used		Designed a men's outfit inspired by the Najdi Al-Burqa cloak with traditional colors and fabrics.	Designed a men's outfit inspired by the Najdi Al-Burqa cloak with traditional colors and fabrics.
Generated phrase		Designed a men's outfit inspired by the traditional winter cloak, with a modern touch that preserves the authenticity in cut and colors.	This modern design is inspired by the Najdi Al-Burqa cloak with a modern touch in the cut, such as tight cuffs, a flowing silhouette, and delicate embroidery.

Visual and Technical Explanation of the Designs:

Design A demonstrates the model's response to text prompts supported by precise Saudi cultural data, incorporating heritage elements from the Najdi region (such as cuts and symbols). In contrast, Design B results from a general prompt not supported by cultural identity and exhibits more abstract and neutral visual features. This contrast was used as a visual indicator to enhance the credibility of both quantitative and qualitative evaluations and to illustrate the impact of model input on shaping the resulting visual identity.

Figure 3: Comparison Between the Cultural Reference and AI-Supported vs. Unsupported Design of the *Jubba*.

Table2

"Figure 3: Comparison between the cultural reference and supported and unsupported AI designs for the Jubba design."

Item	Original (Cultural Reference)	AI-Generated Image (Informed Design A)	AI-Generated Image (Non-Informed Design B)
DI	Inspiration Source	Design A	Design B
Description of	The *Jubba* is an outer garment worn by		

Item	Original (Cultural Reference)	AI-Generated Image (Informed Design A)	AI-Generated Image (Non-Informed Design B)
Cultural Source	men in winter. It is a loose cloak reaching the ankles with an open front. It is worn over basic garments such as the thobe. It features long sleeves and offers comfort and ease of movement.		
Prompt Used		Designed a modern jacket inspired by the traditional Saudi *Jubba*, combining heritage and contemporary elegance.	Designed a jacket inspired by the Saudi *Jubba* with traditional patterns and heritage decorations.
Generated phrase		Designed a modern jacket inspired by the Saudi *Jubba*, merging heritage elements with modern details and fashion trends.	This modern jacket design, inspired by the Saudi *Jubba*, incorporates subtle heritage motifs suitable for daily wear.

Visual and Technical Explanation of the Designs
Design A illustrates the model's response to text prompts supported by accurate Saudi cultural data, incorporating heritage elements from the Najdi region (such as cuts and symbols). In contrast, Design B was generated using a general, non-culturally guided prompt and exhibits more abstract and neutral visual characteristics. This contrast served as a visual indicator that reinforced the credibility of both quantitative and qualitative evaluations and demonstrated the role of model input in shaping the resulting visual identity.

Research Instruments
Expert Evaluation Tool
A specialized digital design evaluation tool (Expert Evaluation Form) was developed and directed to 15 experts in digital fashion and cultural heritage. A standardized evaluation form was used to assess the quality of AI-generated designs based on 9 key dimensions:
• Overall authenticity
• Regional representation
• Traditional cuts
• Used materials
• Color appropriateness
• Embroidery and ornamentation
• Modesty considerations
• Historical accuracy
• Balance between modernity and identity
The tool was designed as an electronic form using a five-point Likert scale.

Visual Questionnaire Tool

A. Visual Questionnaire for Specialists:

A structured visual questionnaire was used and directed at Saudi fashion designers (30) and cultural identity specialists (10). The questionnaire presented pairs of AI-generated designs (A and B), and participants were asked to evaluate each design across four axes:

- Representation of cultural identity
- Visual appeal
- Wearability
- Clarity of cultural inspiration

The questionnaire was visually designed with a five-point Likert scale and distributed electronically via Google Forms, ensuring clarity in the presentation and comparison of each design pair.

Statistical Analysis Mechanism

Data were analyzed using means, standard deviations, independent sample t-tests, and effect size measurement (Cohen's d), in addition to qualitative analysis of open-ended comments and visual impressions.
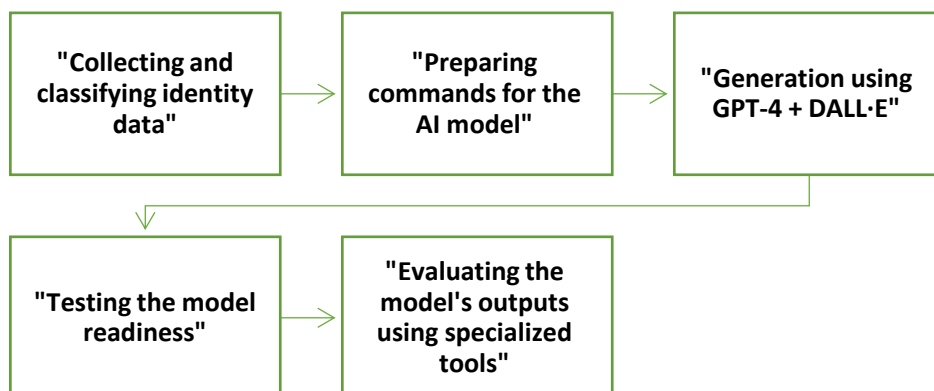

Figure 2: Sequence of Model Development and Output Evaluation Stages in the Study.

Results

The evaluation data were analyzed through two main dimensions: the results of the expert technical evaluation of the generated designs, and the results of the specialists' questionnaire based on the four established criteria.

First: Technical Evaluation Results (n = 15)

The identity-supported designs scored higher across all criteria. The average rating for *authenticity* was 4.6/5, and for *regional representation* it was 4.4/5. In contrast, the non-supported designs received significantly lower averages (*authenticity* = 2.8, *regional representation* = 2.5).

These findings address the first research question: *To what extent do identity-supported designs accurately represent Saudi cultural identity compared to non-supported designs?* The evaluation results showed a statistically significant advantage for the identity-supported designs in terms of authenticity and regional representation.

Second: Visual Questionnaire Results (n = 40)
These results relate to the second research question: *Are there statistically significant differences in the evaluations of the specialists regarding the designs?* The findings confirmed the presence of significant differences across all four axes. Table 1 presents the means and standard deviations of the design evaluations.

Table 3
Means and Standard Deviations of Design Evaluations

Criterion	Group A (Identity-Supported)	Group B (Non-Supported)
Cultural Identity Representation	4.35 ± 0.42	2.68 ± 0.55
Visual Appeal	4.12 ± 0.48	3.15 ± 0.61
Wearability	4.01 ± 0.52	3.05 ± 0.66
Clarity of Cultural Inspiration	4.22 ± 0.47	2.89 ± 0.59

Figure 3 Illustrates the difference in average ratings by specialists between identity-supported designs (Group A) and non-supported designs (Group B) across four main axes: cultural identity representation, visual appeal, wearability, and clarity of cultural inspiration.
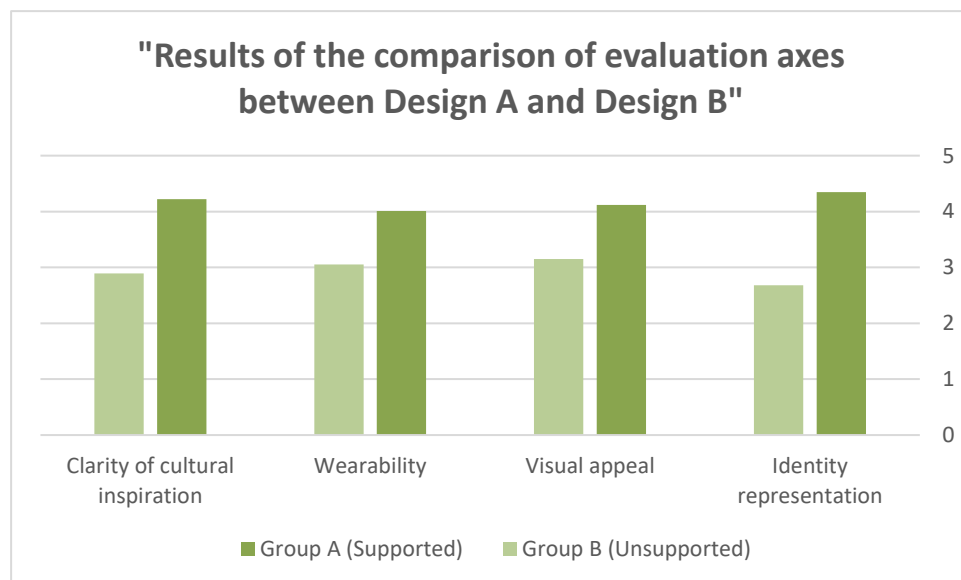

Figure 3: the difference in average ratings by specialists between identity-supported designs (Group A) and non-supported designs (Group B)

Table 4
T-Test Results for Differences Between the Two Groups

Criterion	T-Value	Statistical Significance (p)	Effect Size (Cohen's d)
Cultural Identity Representation	8.24	< 0.001	1.84 (very large)
Visual Appeal	6.75	< 0.001	1.51 (very large)
Wearability	5.98	< 0.001	1.34 (large)
Clarity of Cultural Inspiration	7.41	< 0.001	1.66 (very large)

The values indicate a high level of statistical significance in favor of the identity-supported designs. The very large effect sizes further demonstrate the effectiveness of cultural input in shaping design outcomes.

Qualitative Impressions Analysis

Specialists' comments expressed notable admiration for the visual precision of the identity-supported designs, describing them as "reflecting the spirit of heritage" and "blending authenticity with modernity." In contrast, the non-supported designs were criticized for "lacking cultural context" and "resembling repetitive Western patterns."

These results complement the answer to the third research question, showing that the identity-supported models are capable of generating designs that more effectively express local identity and culture, as illustrated in Figure 6.

Figure 4 shows Distribution of specialists' qualitative impressions of identity-supported and non-supported designs, highlighting a clear advantage in positive feedback for the culturally supported designs.
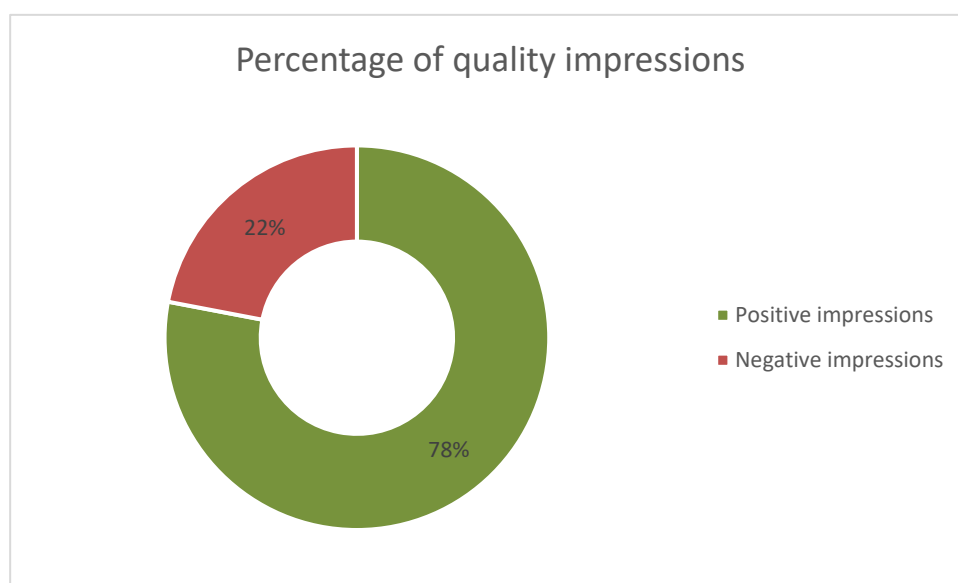

Fig 4 Distribution of specialists' qualitative impressions of identity-supported and non-supported designs

Discussion

The quantitative evaluation results of the culturally supported designs (Group A) and the non-supported designs (Group B) revealed statistically significant differences favoring Group A across all four axes: identity representation, visual appeal, wearability, and clarity of inspiration. The average score for identity representation was 4.35 for Group A compared to 2.68 for Group B, reflecting the substantial impact of feeding the model with accurate cultural data. Clear differences were also observed in other aspects (e.g., clarity of inspiration: 4.22 vs. 2.89), highlighting the strong relationship between cultural background and the perceptual dimension of design.

These findings align with Zhang et al. (2023), who demonstrated that integrating rich cultural databases into AI systems enhances local identity representation in visual outputs. This also supports the study by Lee & Kim (2022), which found that culturally guided models achieve higher visual engagement and broader societal acceptance compared to general models.

The qualitative assessment confirmed these trends, as experts noted that the identity-supported designs exhibited a clear visual reference to cultural identity, whereas the non-supported designs appeared generic, superficial, or borrowed from foreign references. These impressions intersect with Hall's (1997) observation on the centrality of semantic accumulation in visual identity within cultural contexts.

Conversely, some challenges such as repetition or loss of subtle symbols align with the warnings of McCormack & Gervás (2023), who noted that non-culturally informed models may produce stereotypical or contextually inappropriate representations. This underlines the importance of refining textual prompts and expanding the scope of local datasets used for model training.

Accordingly, this study provides empirical support for the notion that the effectiveness of generative models should not be measured solely by aesthetic output, but by their capacity to accurately convey cultural depth. This reinforces the call for developing Culturally Informed Generative Models that integrate technology with anthropological knowledge and local context.

Conclusion and Recommendations
This experimental study demonstrated that AI generative models can serve as effective tools for visually representing cultural identity, provided they are trained on well-structured and contextually informed cultural data. Identity-supported designs significantly outperformed others in expert evaluations, highlighting the importance of systematically integrating cultural elements into prompt structures and training databases.

The findings indicate that generative design cannot be separated from its cultural context. Aesthetic outputs lose meaning if they do not reflect symbolic and artistic values linked to the identity of the user or producing community. The study also confirms that general models, despite their technical power, remain limited in representing cultural specificities unless culturally adjusted.

Study Recommendations
1. Develop culturally informed generative tools that respect the contextual uniqueness of different communities.
2. Adopt cultural evaluation as a primary criterion for analyzing the quality of generative outputs, alongside visual appeal and innovation.
3. Encourage collaboration between data scientists and experts in heritage and identity to build rich, representative databases.
4. Expand future research to test these models in real-world applications involving designers and end users.

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