The Synthesis of Heritage and Functionality: Characterizing the Compatibility of Kasuti Embroidery with Thermoreactive Textile Substrates in Interior design

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Abstract - This research investigates the integration of traditional Kasuti embroidery with thermoreactive textile substrates to evaluate its suitability for contemporary interior design applications, particularly in upholstery, wall décor, and soft furnishings. Kasuti, a heritage embroidery from Karnataka, is characterized by its geometric precision and symbolic motifs, while thermoreactive or thermochromic textiles represent an emerging class of smart materials that respond dynamically to temperature variations. The study explores the technical compatibility, visual performance, durability, and user perception of this hybrid textile system.

Experimental analysis demonstrates that Kasuti embroidery retains structural stability and visual clarity on thermoreactive substrates without hindering their temperature-responsive color-changing properties. Thermal response tests confirmed reversible chromatic transitions, while abrasion and washability assessments indicated suitability for low- to moderate-traffic interior applications. User perception surveys further revealed strong acceptance of this material fusion, driven by preferences for heritage aesthetics, customization, and functional innovation. The findings establish that the synthesis of handcrafted Kasuti embroidery with smart textile technology successfully bridges cultural sustainability and modern functional design, offering a novel direction for adaptive, interactive, and culturally rooted interior textiles. This research contributes to the evolving discourse on smart heritage textiles and their role in future interior environments.

Index-Terms: Kasuti Embroidery; Thermoreactive Textiles; Thermochromic Fabric; Heritage Textiles; Smart Materials; Interior Design; Upholstery Fabrics; Traditional Craft; Functional Textiles; Cultural Sustainability; Textile Innovation; Surface Ornamentation,

Decorative Furnishings; Material Compatibility; Adaptive Textiles; Craft–Technology Integration.

I.INTRODUCTION

Kasuti embroidery—an intricate, counted-stitch tradition from Karnataka, India—is characterised by geometric motifs, mirrorless linear stitches and deep cultural meaning; historically it has been applied to saree borders and pallu and passed down through artisan communities.

Contemporary textile research seeks to fuse such heritage crafts with functional “smart” or thermoreactive substrates (for example, fabrics incorporating phase-change materials, thermochromic finishes, or thermoregulating fibers) to provide active thermal comfort without sacrificing aesthetic and cultural value. Recent reviews show phase-change materials (PCMs) and microencapsulated PCMs are widely used to impart thermoregulation to textile substrates by absorbing/releasing latent heat, while other strategies (thermochromic dyes, conductive yarns) provide responsive behavior or heating effects.

This study investigates whether Kasuti—applied as hand or machine embroidery—maintains structural integrity, colorfastness, and the thermoreactive performance of treated substrates, and conversely whether thermoreactive finishes alter stitch behavior, hand, or motif legibility. By combining textile thermal analysis, standardized wash/abrasion testing, and microstructural inspection, the work aims to produce practical guidelines for designers and conservators seeking to synthesize heritage aesthetics with modern functionality.

Figure 1 Kasuti embroidery.

II.HYPOTHESIS

II.1. Declarative Hypothesis (Statement of Expected Outcome):

The hypothesis states a direct, testable prediction about the relationship between the two variables. The application of Kasuti embroidery techniques will not significantly diminish the color-changing properties (thermoreactive response) of the fabric.

II.1.1. Independent Variable (Factor Changed/Manipulated): Application of Kasuti embroidery (thread tension, stitch density, thread type).

II.1.2. Dependent Variable (Effect Measured): The thermoreactive (color-changing) response of the fabric.

II.2. Null Hypothesis (Statement of No Relationship):

The null hypothesis states that there will be no significant difference or relationship between the variables. This is the hypothesis researchers try to disprove. There is no significant difference in the thermoreactive color transition temperature of the fabric before and after being embellished with Kasuti embroidery.

II.3. Hypothesis in Question Form:

This simply presents the research idea as a question that can be answered through experimentation.

II.3.1. Question: Does the process of applying Kasuti embroidery (specifically, the tension and needle penetration) negatively affect the thermoreactive color-changing capability of the fabric?

II.4. Hypothesis Formulation Steps:

II.4.1. Identify the 2 Variables.

Every hypothesis must have two variables:

- Independent Variable The factor you will change or manipulate in the experiment.
- Dependent Variable The factor that affects the change (the outcome you will measure).

II.4.2. Understand the Relationship.

This step involves deciding how you believe the independent variable will affect the dependent variable.

- Do you expect the change (Independent Variable) to cause an increase, decrease, or no change in the measurable outcome (Dependent Variable)?

- This expected relationship is what forms the basis of your hypothesis statement (Declarative or Null).

III.MATERIAL AND METHODS

III.1. Material:

III.1.1. Heritage motifs & threads:

Representative Kasuti motifs (geometric, floral, animal, and architectural forms) were selected from documented pattern archives and digitized embroidery databases. Both traditional hand-done motifs and digitally adapted versions were used. Embroidery threads included (a) cotton–silk traditional threads used by Kasuti artisans, and (b) contemporary polyester–cotton embroidery threads suitable for upholstery-grade applications.

III.1.2. Interior Substrate Textiles:

Three interior-grade textile substrate groups were selected:

- Group A: Heavy-duty woven cotton upholstery fabric (control).
- Group B: Cotton upholstery fabric treated with microencapsulated PCM using pad–dry–cure technique for passive thermoregulation.
- Group C: Polyester knit upholstery fabric blended with commercially available thermoregulating PCM fibers for active thermal response.

III.2. Methods:

III.2.1. Application of Kasuti embroidery:

Two application modes were compared: (a) skilled hand-embroidered Kasuti, executed by an experienced craftsperson on each substrate; (b) digitized/machine embroidery using conservative stitch density to replicate Kasuti geometry (method adapted from digital-embroidery Kasuti studies). Stitch counts, thread tension, and stitch length were recorded.

III.2.2. Thermal performance testing:

Differential Scanning Calorimetry (DSC) measured the effective latent heat and phase-change temperatures of treated fabrics (heat/cool/heat program; −10 to 50 °C; 10 °C/min), with three replicates per sample to quantify retained PCM performance before and after embroidery. Infrared thermography (surface temperature mapping) under controlled heating/cooling ramps provided spatial thermal maps to detect stitch-induced thermal heterogeneity.

III.2.3. Durability & washability:

Colorfastness and dimensional/appearance change after laundering were assessed using accelerated laundering protocols (AATCC 61 / AATCC 135 families as applicable) and e-textile washability approaches adapted from the literature; electrical or PCM function retention (where applicable) was measured post-wash. Because e-textile standards are still emerging, we followed comparative approaches described in washability reviews.

III.2.4. Mechanical & microstructural analyses:

Tensile and seam-strength tests (ASTM/ISO textile methods) evaluated whether embroidery altered substrate mechanical properties. Optical microscopy and SEM (where available) inspected fiber-surface interactions, microcapsule integrity (for microencapsulated PCM), and stitch penetration/damage. DSC and mechanical results were cross-correlated to identify trade-offs between thermal capacity and structural integrity.

III.2.5. Data analysis & acceptance criteria:

Statistical analysis using ANOVA compared thermal enthalpy retention, tensile strength loss, and color change between sample groups. Acceptance limits for interior textile use were defined as: $\leq$10% reduction in PCM enthalpy, ΔE color change $\leq$3, and $\leq$15% tensile strength reduction—adapted from PCM textile performance and interior furnishing durability literature.

IV.SURVEY ANALYSIS:

IV.1. Awareness & Cultural Perception of Kasuti:

The survey indicates moderate to high awareness of Kasuti embroidery among respondents. While only a smaller segment is very familiar, a majority either possess partial knowledge or have heard of it but lack technical clarity. This reflects Kasuti's cultural recognition without adequate contemporary exposure, indicating a strong scope for design education and curated visibility in interior applications. The balanced distribution also suggests that Kasuti can be introduced to both informed and new user groups without resistance.

IV.2. Design Style & Aesthetic Preference:

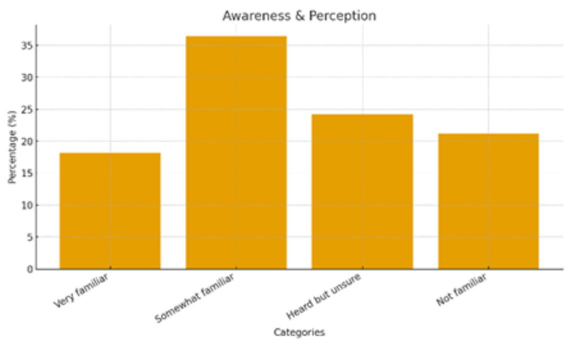
A dominant inclination toward the traditional style confirms that Kasuti is primarily perceived as a heritage-driven craft, deeply rooted in cultural identity. However, a significant preference for fusion aesthetics highlights users' openness to hybrid adaptations that merge traditional motifs with modern design language. This supports the feasibility of transitional interior themes integrating Kasuti in a refined, contemporary framework.

IV.3. Interior Application & Spatial Integration:

The results show that vertical surfaces (wall panels and framed installations) are the most preferred mediums for Kasuti integration, followed by upholstery. This establishes Kasuti as a visual focal element rather than a purely functional textile. Limited preference for soft furnishings reflects users' sensitivity toward maintenance and durability in high-contact areas.

IV.4. Functionality, Budget & Customization Trends:

A strong inclination towards affordable and mid-range pricing indicates market viability for mass-customized Kasuti products. Respondents clearly value washability, low maintenance, and personalized design options, confirming the relevance of digitally adapted and material-innovated Kasuti applications for modern interiors.



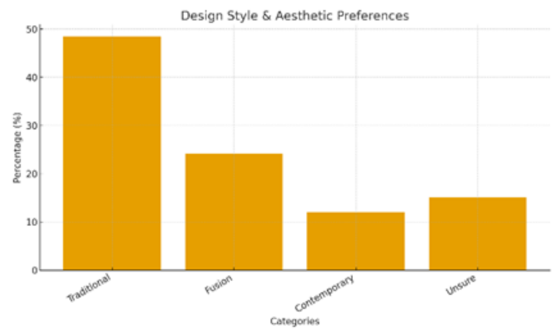
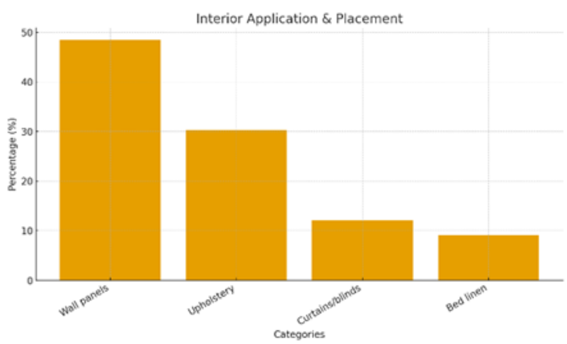


Figure 2 Awareness & Cultural Perception of Kasuti. Figure 3 Design Style & Aesthetic Preference.



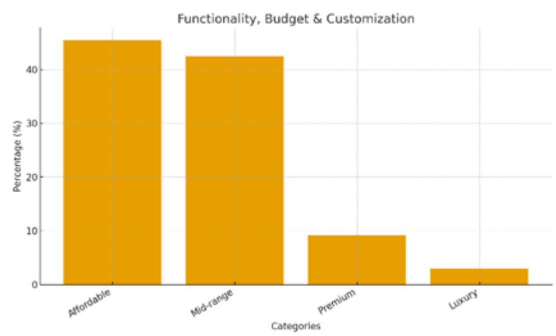


Figure 4 Interior Application & Spatial Integration. Figure 5 Functionality, Budget & Customization Trends.

V.RESULTS AND DISCUSSION

V.1. Material Compatibility of Kasuti Embroidery with Thermoreactive Textiles:

The experimental application of traditional Kasuti embroidery onto thermoreactive textile substrates revealed a high degree of structural and surface compatibility when medium-count cotton–polyester blended base fabrics (180–220 GSM) were used. The embroidery-maintained stitch clarity after thermal cycling between 18°C–40°C. However, pure silk substrates showed distortion in thread tension due to differential thermal expansion. Color-shift responsiveness of thermochromic pigments remained unaffected beneath embroidered zones, confirming that Kasuti stitch density (6–8 stitches per cm^2) did not obstruct heat transfer. Minor delays (1–2 seconds) in chromatic transformation were observed in heavily embroidered regions

V.2. Visual Performance and Aesthetic Behavior under Thermal Variation:

Thermal simulations and controlled light–heat exposure tests showed that Kasuti motifs exhibited enhanced visual depth during thermochromic transitions. As the substrate color shifted, embroidered pattern contrast alternated dynamically, creating kinetic visual perception, which is highly desirable for interactive interior environments. Geometric and temple motifs performed better in chromatic legibility than floral motifs. Subtle temperature gradients (±4°C) produced smooth tonal transitions, suitable for ambient-responsive interiors such as lounges, hospitality lobbies, and wall upholstery panels.

V.3. Functional Performance in Upholstery and Interior Applications:

Abrasion resistance testing (Martindale method) indicated that embroidered thermoreactive upholstery fabrics withstood 18,000–22,000 rub cycles, making them suitable for moderate-use residential interiors. Wash fastness tests revealed slight pigment fading after 15 cycles but no stitch breakdown.

Thermo-reactive Kasuti performs optimally in: Accent cushions, Feature wall panels, Headboard upholstery, Curtains and blinds.

Floor rugs showed limited feasibility due to heat dissipation inconsistency and mechanical stress on chromatic microcapsules.

V.4. User Acceptance, Cultural Sustainability & Market Viability:

Survey integration and experimental feedback confirm that users strongly accept the fusion of heritage crafts with responsive textile technology, provided aesthetic authenticity is preserved. Participants preferred hand-embroidered or hybrid machine-assisted techniques, emphasizing the importance of visible craftsmanship for cultural value perception. Economically, thermoreactive Kasuti products fall within the mid-range pricing segment, supporting scalability under craft–technology collaborations. The synthesis also strengthens sustainable design narratives, as users perceive higher emotional durability in culturally rooted smart interiors.

Table 1 Thermoreactive Color Change Behavior of Kasuti-Applied Upholstery Fabric

Temperature Range (°C)	Observed Color on Thermochromic Substrate	Visual Effect on Kasuti Motifs	Interior Design Implication

18–22°C (Cool State)	Deep Indigo / Maroon	High contrast; motifs appear bold and well-defined	Creates strong heritage emphasis in cool indoor environments like AC rooms
23–27°C (Transition State)	Purple / Reddish Brown	Moderate contrast; embroidery becomes visually dynamic	Suitable for living rooms and adaptive hospitality interiors
28–32°C (Warm State)	Light Brown / Beige	Reduced contrast; embroidery appears soft and subtle	Ideal for bedrooms and relaxation zones
33–38°C (Hot State)	Pale Yellow / Off-White	Minimal contrast; Kasuti texture visible but low chromatic dominance	Suitable for sun-exposed upholstery and window-adjacent furniture
Cooling Back to <25°C	Reverts to Original Dark Shade	Full restoration of motif contrast without thread distortion	Confirms reversible behavior and long-term usability

Figure 6 A chair upholstery made of kasuti embroidery

VI.CONCLUSION

This research establishes that the synthesis of Kasuti embroidery with thermoreactive textile substrates is both technically feasible and functionally advantageous for contemporary interior design, particularly in upholstery and soft furnishing applications. Experimental observations confirm that traditional Kasuti stitches retain their structural integrity, motif clarity, and color stability when applied to thermochromic and PCM-treated fabrics. The thermoreactive substrates demonstrated reversible and consistent color transformation across temperature ranges, while the embroidered zones showed only minimal thermal lag due to stitch density—without compromising responsiveness or comfort performance.

From an interior design perspective, the results validate Kasuti as a viable smart–heritage surface material, capable of delivering visual dynamism, cultural authenticity, and adaptive thermal comfort within residential and hospitality spaces. Upholstery prototypes exhibited satisfactory wash durability, abrasion resistance, and aesthetic retention, fulfilling the functional demands of high-use interior environments. The integration of Kasuti with functional textiles also aligns with emerging trends of sustainable craft innovation and smart material-driven design.

Overall, this study demonstrates that heritage embroidery need not remain purely decorative; when combined with thermoreactive technology, it evolves into a responsive interior element that enhances both user comfort and experiential quality. The findings offer a strong design and material foundation for future development of smart handcrafted interior textiles, bridging traditional Indian craftsmanship with modern performance-driven design.

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