



Original Research

Symbiosis of Knowledge: Ancestral Textile Crafts and Digital Design

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Abstract: As digitalization transforms creative and productive processes, manual textile learning practices are increasingly marginalized within design contexts, often regarded merely as hobbies. This shift has contributed to the erosion of cultural and ancestral memory, as well as to the decline of creativity and manual textile craftsmanship. While digital tools expand opportunities for experimentation, speed, and precision, they also distance designers from the sensory, material, and communal dimensions that have historically sustained textile knowledge. Promoting cultural sustainability in fashion design requires rethinking the relationship between technological innovation and ancestral modes of making. Grounded in theoretical reflection, this study argues for a symbiotic relationship between ancestral craft and digital design, understanding them as complementary epistemologies capable of sustaining creativity and cultural continuity through fashion. Drawing on studies of textile and cultural practices in Northern Portugal, it discusses how digital technologies can function as mediators of tradition rather than as its replacements, enabling new forms of documentation, reinterpretation, and transmission of inherited knowledge. By framing fashion design as a field essential to the continuity of ancestral textile knowledge, the study repositions the digital not as an antagonist to craft but as a potential partner in the preservation and renewal of textile heritage. The study concludes by reflecting on the need to rethink new, hybrid, and culturally sensitive models of design education that recognize both the hand and the algorithm, as well as memory and technology, as coexisting forces in shaping sustainable futures in fashion design.

Keywords: *Crafts, Cultural Sustainability, Digital Design, Fashion Design, Hybrid Methodologies*

Introduction

In recent decades, technological advancements have profoundly transformed the creative, productive, and pedagogical landscapes of design and fashion. This transformation has shifted textile expertise from embodied and manual knowledge toward increasingly digitized workflows (Oevermann et al. 2022; Zbucha 2022). Consequently, this shift privileges the acceleration and simplification of product development at the expense of tactile qualities, material subtleties, and irregularities that historically underpinned the authenticity and sensory value of handcrafted textiles (Falk 2022; Zbucha 2022). As manual techniques become progressively marginalized within professional practice, the intrinsic relationship between maker and material is correspondingly transformed. Paradoxically, digital technologies can also ensure the materialization of intangible cultural heritage (ICH) and

collective memory through ethnographic, digital, and augmented approaches that document, preserve, and reinterpret making traditions across time and space (Casciani and Vandi 2022). Tools such as three-dimensional systems, digital drawing and modeling, augmented reality, virtual archives, creations developed with artificial intelligence (AI), and communication platforms have expanded the possibilities for experimentation, speed, and precision, thereby redefining the relationship between the artisan, designer, material, and time.

This context can be understood through the Industry 4.0 paradigm, characterized by the fusion of technologies that dissolve the boundaries between the physical, digital, and biological spheres. In fashion, such transformation entails a shift from predominantly mechanical or manual processes to an interconnected ecosystem in which data, algorithms, and automated systems directly influence ideation, prototyping, and production. According to Lee (2025), Industry 4.0 demands near-immediate responses to global dynamics, in which the use of digital technologies, including generative artificial intelligence (GenAI), significantly reduces the time between conception and materialization, thereby shortening production cycles and expanding the creative process. This shift establishes an era of symbiosis where the designer harnesses digital potential to intensify the physical, sensory, and cultural expression of products (Lee and Lee 2022).

Despite this transformation, discourse on technological innovation has frequently been associated with the marginalization of craft (Dormer 1995) and the gradual disappearance of ancestral textile knowledge, both of which come to be perceived as cultural remnants of the past, disconnected from innovation. This perception is grounded in a dichotomy between technology and craft, consolidated since the early twentieth century, when confidence in technological progress intensified with the advancement of industrial systems (Dormer 1995). This tension is further reinforced by contemporary perspectives that highlight a persistent difficulty in recognizing the continued relevance and existence of traditional craft and industrial professions in general (Ionică 2022).

Within fashion design, this marginalization is intensified by its historical positioning as a feminized and often secondary field, associated with domestic space, despite its role as a site of cultural expression and social values. The relationship between clothing, design, and craft is essential for understanding how cultural identity and symbolic meaning are continuously reinserted into society through fashion production. Nevertheless, ancestral female craft practices, such as embroidery and weaving, have frequently been excluded or minimized in academic discourse due to their association with domesticity and their distance from modernist and industrial paradigms. This reinforces what has been described as an elitist and exclusionary conception of design (Schulz and Ferreira da Cunha 2024).

Extending this line of critique, this dichotomous reading of technology and craft has been widely challenged in contemporary design literature. According to Yelavich (2025), the separation between craft, design, and technology is relatively recent in Western cultural history. Before the seventeenth century, artists, artisans, and technicians shared similar

working methods and were often understood as participants in a common ecosystem of technical and material knowledge production. The author argues that the renewed convergence of these spheres in the contemporary context allows design to be understood not only as the production of objects but as a relational practice that articulates tools, materials, knowledge, and social contexts.

Furthermore, Yelavich (2025) argues that the relationship between craft, design, and technology has often been framed through binary or hierarchical models, in which the artisanal is associated with the past and the technological with the future. The author argues that the proliferation of digital technologies and novel manufacturing processes challenges conventional understandings of authorship, materiality, and the very act of “making,” fostering a space of productive tension in which artisanal practices and technological systems engage with and mutually reshape one another.

Supporting this argument, the author identifies the textile domain as an emblematic case of this historical intersection between artisanal technique and technological development. For Yelavich (2025), the punched cards used in mechanical looms anticipate fundamental principles of modern computing, demonstrating how technological innovation often emerges from artisanal practices and textile systems.

Historically, craft has constituted a starting point for industry, as through manual techniques, creativity, and natural materials, human beings developed textile solutions that established aesthetic, technical, and cultural references within the fields of design and fashion (Schulz 2021). In this sense, craft may be understood as the first technology of fashion, as the systems of creation, formal codes, and material languages associated with textile production have their roots in artisanal practices, constituting a body of knowledge accumulated and transmitted across generations (Caires 2025; European Crafts Alliance and Ohayo Brand Curation S.L. 2024; Schulz 2021; Veerman 2024).

Contemporary studies have challenged the notion that traditional crafts are inherently “low-tech” or that digital technology alienates artisans, instead affirming technology’s active role within craft (Caires 2025; Casciani and Vandi 2022; Cesário 2025; European Crafts Alliance and Ohayo Brand Curation S.L. 2024; Pentescu 2023; Veerman 2024; Wang and Alli 2025). The etymology of the word “technology” refers to a “discourse or treatise on art and craft,” indicating that the use of tools—whether manual, mechanical, or digital—has always been intrinsically linked to the development of artisanal knowledge. From this perspective, technologies associated with craft emerge from tradition itself, driven by artisans’ creativity in optimizing resources, improving quality, and expanding technical possibilities (European Crafts Alliance and Ohayo Brand Curation S.L. 2024).

Within the domain of intangible culture, ancestral textile knowledge constitutes a living heritage that encompasses gestures, rhythms, narratives, techniques, and modes of intergenerational transmission, deeply rooted in territorial and community contexts. As argued by UNESCO (2003), ICH includes social and cultural practices, including oral traditions,

customs, languages, artistic expressions, and craftsmanship, transmitted within communities. The persistence of this knowledge in the contemporary world, and its future projection, depends not only on oral transmission across generations but, above all, on its capacity to engage with contemporary contexts, incorporating new technological mediations without compromising the cultural values that sustain it, in a sense of mutual coexistence (Caires 2025).

Caires (2025) proposes the concepts of dematerialization and hybridization to describe processes in which digital tools are mobilized to reinterpret and transform the materiality of textile artifacts, giving rise to hybrid creative practices that articulate artisanal tradition and technological experimentation (Caires 2025; Casciani and Vandi 2022).

Digital technologies may be understood as strategic allies in the safeguarding and revitalization of ICH, enabling the documentation, preservation, and reinterpretation of ancestral textile knowledge through new creative languages and experimental processes (Caires 2025; Casciani and Vandi 2022; Veerman 2024).

Fashion design thus assumes a central role as a mediating field between artisanal ancestry and technological innovation. By integrating traditional textile practices into contemporary design processes, fashion design can foster hybrid creative languages capable of articulating cultural memory and technological experimentation. In this context, digital tools not only function as means of reproduction and technical efficiency but as devices that expand the field of creative imagination (Veerman 2024).

At present, ICH faces significant challenges in terms of transmission and preservation, requiring the strategic transformation of artisanal processes (Wang and Alli 2025). At the same time, a process of renewal of these heritages can be observed, driven by creative reinterpretations emerging from the field of design and using digital technologies as new forms of cultural communication (European Crafts Alliance and Ohayo Brand Curation S.L. 2024). Although the combination of these two domains may appear paradoxical, craft and technology have always been interconnected, insofar as traditional processes drive the development of new tools, while technologies offer a means of ensuring the continuity of ancestral cultural knowledge. Within this framework, it becomes particularly relevant to deepen the understanding of how these interactions may be critically mobilized in contemporary design and within the context of fashion design education.

Thus, this article seeks to address two central questions: (1) How can a synthesis between ancestral textile knowledge and digital design be fostered to strengthen ICH and stimulate hybrid creative languages in fashion design? (2) How can fashion design education integrate, in a critical and culturally sensitive manner, both manual and digital competencies, ensuring the continuity of textile knowledge as ICH?

In addressing these questions, the article proposes a theoretical reflection that frames digital technologies not as substitutes for artisanal practices but as mediators capable of enhancing their visibility, documentation, and reinvention in the contemporary context. Through a critical analysis of the literature and the discussion of initiatives that articulate

tradition and innovation, it seeks to demonstrate how the convergence between ancestral knowledge and digital tools may contribute simultaneously to the safeguarding of ICH and to the expansion of creative practices in fashion design.

The article is organized as follows: the “Methodology” section presents the research approach and the procedure used to select and analyze the case studies. The “Analysis” section is organized into four subsections: “The Digital Turn in Fashion”; “Transformations in Creative Processes”; “Digital Technologies as Mediators of Ancestral Textile Knowledge,” examined through four case studies; and “Implications for Fashion Design Education.” The “Discussion” section introduces the “Symbiosis of Knowledge” framework as a synthesis of the findings, and the “Conclusion” section brings the study to a close.

Methodology

This study adopts a qualitative, theory-driven approach based on critical literature analysis and case study interpretation. It does not aim at statistical generalization but at developing a conceptual understanding of how ancestral textile knowledge interacts with digital technologies within contemporary fashion design, and how these dynamics inform educational practices. The analysis is informed by literature on design studies, cultural heritage, and technological transformation.

The empirical component comprises four case studies in Portugal: Casa do Risco de Felgueiras, the Programa Nacional Saber Fazer, Susana Bettencourt, and Paatiff by José Sobral. These cases were selected through purposive sampling according to three criteria: (1) relevance to textile cultural heritage and ancestral textile knowledge, (2) engagement with digital technologies, and (3) diversity of institutional and creative contexts.

Portugal has a historical textile tradition and ancestry, particularly in the northern region, where artisanal production and industrial textile systems coexist and contribute to the country’s economic and cultural development (Cabreira and Braga de Macedo 2022; Nogueira 2020). It also provides a context in which digital transformation intersects with design practice, heritage initiatives, and fashion design education.

The analysis is guided by a thematic framework structured around four categories: (1) textile heritage and ancestral knowledge, (2) digital mediation of craft practices, (3) hybridization between manual and digital processes, and (4) educational and cultural implications. These categories operate as analytical lenses for examining each case and identifying patterns and tensions.

Each case is analyzed individually and positioned within the conceptual model proposed in this study. The focus is not on comparison per se but on how cases operate as situated configurations of the dynamics under investigation. Finally, as a qualitative study, the research acknowledges the role of the researcher in the construction of meaning, integrating empirical observation with conceptual interpretation.

Analysis

The Digital Turn in Fashion Design

To address the central questions of this study, this section analyzes the digital turn in fashion design and its impacts on creative, educational, productive, and cultural processes. From a critical perspective, it examines how digital technologies may expand the possibilities of contemporary design while simultaneously posing challenges to the continuity of ancestral textile knowledge, thus exploring the relationships between human sensibility, digital technologies, and ICH. Within this framework, it is assumed that creative processes in fashion design remain grounded in sensory experimentation, materiality, and the designer's project-based thinking, dimensions that constitute the human foundation of creative practice. At the same time, digital technologies may act as extensions of these processes, enabling the translation of gestures, patterns, and traditional textile knowledge into new formats of experimentation and analysis (Brown and Vacca 2022; Santiago et al. 2026).

Therefore, this digital turn does not replace artisanal practices or human sensibility but rather enables the emergence of hybrid forms of creation, in which the interaction between ancestral knowledge and technological mediation may generate new material, aesthetic, and cultural outcomes. In this context, the concept of a "dynamic tradition" (Kofler and Walder 2024) refers to a form of tradition that is not fixed or static but continuously reconfigured through contemporary practices, where heritage and innovation coexist and mutually reshape one another. Within this framework, textile cultural heritage is continually reinterpreted through contemporary creative processes. From this perspective, digital technologies may be understood as instruments that expand the possibilities for documenting, experimenting with, and transmitting textile knowledge, contributing to cultural sustainability that keeps this knowledge alive in the contemporary context (Veerman 2024). Building on this framework, the following section analyzes how these dynamics establish the conceptual basis for discussing the relations between technology, textile craft, and fashion design education.

Transformations in Creative Processes

The digital turn in fashion design represents a profound transformation in creative processes, altering not only the tools employed but also how fashion products are conceived, developed, and understood. Although the presence of digital technologies in contemporary design is widely associated with AI, whose rise intensified in the 2000s and gained particular visibility during the COVID-19 pandemic (Lee 2025; Queiroz Campos 2023), the incorporation of digital technologies in design dates back to the 1990s, with the introduction of Computer-Aided Design (CAD) tools, which progressively shifted the focus from manual to digital representation. This transition also contributed to a broader epistemological shift toward an

ontological understanding of design, one that conceives designing not only as the creation of objects but as a process that shapes ways of being, acting, and relating in the world (Yelavich 2025). This trajectory frames the emergence of AI not as an isolated rupture but as a new phase in the transformation of creative processes in fashion design, expanding the possibilities for exploring forms, structures, and languages.

The advancement of these digital technologies, particularly AI tools, has enabled the creation of new visual and conceptual content by identifying and replicating patterns derived from large volumes of data, including images, models, and other forms of creative representation (Santiago et al. 2026). In this context, technology no longer functions merely as a technical instrument but assumes an active role in the design process, fostering exploratory and experimental approaches and expanding the visual repertoire available to designers. By supporting the rapid formulation and evaluation of multiple creative hypotheses, these tools broaden design exploration beyond conventional pathways (Santiago et al. 2026).

Beyond the conceptual domain, digital technologies exert a direct impact on design and production practices in fashion. In the context of contemporary fashion design and craft, digital modeling, simulation, and three-dimensional visualization allow for the partial replacement of physical prototypes with virtual experimentation, contributing to the optimization of time, resources, and materials throughout the development process (Veerman 2024). These tools introduce greater flexibility into the creative process, enabling rapid testing of formal, structural, and chromatic variations before physical materialization, thereby broadening the scope for experimentation. This shift aligns with perspectives interpreting design as an ontological practice. For Yelavich (2025), design is not limited to the production of artefacts but actively participates in shaping the conditions through which human beings relate to the material and technological world. From this viewpoint, digital tools, materials, and artisanal processes do not operate in isolation but as elements of a relational system that simultaneously influences ways of making, thinking, and inhabiting the world.

However, these transformations also introduce a set of critical tensions within the fields of fashion design and artisanal practice. Among the principal risks identified in the literature (Casciani and Vandi 2022; European Crafts Alliance and Ohayo Brand Curation S.L. 2024; Schulz and Ferreira da Cunha 2026; Veerman 2024; Wang and Alli 2025) are the potential marginalization of ancestral textile knowledge, cultural homogenization resulting from the global circulation of visual references, and the devaluation of manual labor when reduced to a merely decorative or recreational dimension. These tensions highlight the challenge of ensuring that the incorporation of digital technologies does not render local cultural identities invisible.

At the same time, the digital turn also opens strategic opportunities for the reinterpretation and valorization of these practices. When mobilized critically, digital technologies may contribute to optimizing production stages, reducing development costs, and enhancing the competitiveness of products grounded in artisanal knowledge. Within this

framework, the integration of traditional practices and digital tools may foster the emergence of a “dynamic tradition,” in which ancestral knowledge is continuously reinterpreted through contemporary creative processes (Kofler and Walder 2024; Veerman 2024).

Within this balance between tensions and opportunities, human sensibility assumes a central role. Creativity, design thinking, and the designer’s sensory experience continue to guide creative decisions, while digital technologies function as supportive tools that expand the possibilities for experimentation and analysis. Thus, rather than replacing the human gesture, technology tends to act as an extension of creative thought, enabling the translation of gestures, patterns, and traditional textile knowledge into new formats of visual, material, and conceptual exploration (Santiago et al. 2026).

In this sense, the digital turn in fashion design may be understood as a process of expanding the creative and operational capacities of the designer, in which technological innovation and human sensibility are articulated in a complementary manner. While these transformations bring evident gains in terms of efficiency, innovation, and formal freedom, they also raise significant challenges regarding the preservation of material sensibility, embodied gesture, and the knowledge embedded in artisanal practices. These issues will be further explored in the following sections, which examine the relationships between textile heritage, technological mediation, and fashion design education.

Digital Technologies as Mediators of Ancestral Textile Knowledge

The integration of digital technologies into fashion design extends beyond the mere transformation of creative processes, assuming a mediating role between ancestral artisanal knowledge and contemporary design practices. Within the context of craft and ICH, artisans act as custodians of knowledge, practices, and expressions inherited from the past, transmitted through experience, gesture, and hands-on learning (Casciani and Vandi 2022). However, this knowledge faces a condition of vulnerability due to the fragility of intergenerational transmission mechanisms, the declining interest among younger generations, and the difficulty of competing with mass production models (Lourenço and da Silva Ribeiro 2025). In this sense, digital technologies operate strategically by documenting, preserving, and reinterpreting artisanal practices without compromising the historical, cultural, and material complexity of making (Casciani and Vandi 2022; Veerman 2024). As Veerman (2024) further emphasizes, these tools expand artisanal practice while preserving its non-automatable dimensions. Within this relational framework, the convergence of craft, design, and digital technologies can be interpreted as a process of “world-making”—a concept mobilized by Yelavich (2025) to describe how design practices contribute to shaping cultural and material realities. When artisanal knowledge is integrated into design processes supported by digital technologies, the objective is not only to preserve traditional techniques

but to generate new cultural configurations in which memory, materiality, and technological innovation coexist.

Design thus assumes a central role as a mediating agent. From a design-oriented perspective, methodologies inspired by ethnography and design thinking enable the integration of dispersed artisanal knowledge into the fashion system, fostering products and systems that incorporate local knowledge, cultural identity, and narratives rooted in their territories of origin (Casciani and Vandi 2022; Veerman 2024). This critical articulation between tradition and contemporaneity generates, according to Brown and Vacca (2022), a collaborative ecosystem oriented toward cultural sustainability and the reinforcing of living heritage.

At the same time, the integration of digital technologies introduces critical tensions that cannot be overlooked. Among the risks identified in the literature are the marginalization of ancestral textile knowledge, cultural homogenization driven by the global circulation of visual references, and the devaluation of manual labor when reduced to a merely decorative or recreational role (Caires 2025; Casciani and Vandi 2022; European Crafts Alliance and Ohayo Brand Curation S.L. 2024; Veerman 2024; Wang and Alli 2025; Zbucha 2022). These concerns are further reinforced by structural conditions of artisanal labor. Artisans often operate in precarious economic contexts, being compensated per piece rather than by working time. In many cases, they function as informal freelancers and experience geographic marginalization or displacement, contributing to broader asymmetries in value distribution within design and production systems. The resulting challenge lies in the development of collaborative models between designers and artisans that avoid reducing craft practitioners to low-cost labor within design-led production chains. This issue is particularly relevant in the field of fashion, where creative processes have historically drawn upon cultural, artistic, and historical references as sources of aesthetic and narrative innovation (Schulz and Ferreira da Cunha 2026). These dynamics also raise ethical concerns regarding cultural appropriation, authenticity, and visibility of material practices. When incorporated into the fashion industry through simplified or stereotypical approaches, they often result in the invisibility of people, cultures, and material practices (Zbucha 2022).

From this perspective, the translation of such knowledge into digital environments entails processes of abstraction that may prioritize technical aspects at the expense of the historical, cultural, and material complexity of artisanal making. Caires (2025) warns that deeply rooted competencies risk being reduced to a mere “hobby,” as algorithms operating on large volumes of data may overlook the social interactions that structure artisanal practices. Veerman (2024) further argues that mediation should be understood as an interdependence, in which material sensibility continues to guide digital solutions.

The European Crafts Alliance report (2024) highlights these ambiguities, revealing that 66.7% of artisans identify design as the area with greatest technological advancement, while 69.7% have already integrated digital tools such as CAD, 3D printing, Computer Numerical Control (CNC), laser cutting, and Adobe software. Although 76.74% recognize increased

competitiveness, barriers persist in costs, learning time, and articulation with traditional methods. These findings indicate that challenges extend beyond technology, encompassing cultural, educational, and systemic dimensions. They demonstrate that the principal future challenges for the craft sector include education and training, digital competencies, production digitalization, resource scarcity, sustainability, and globalization impacts (Kofler and Walder 2024).

However, these tensions should not be interpreted solely as problematic. For Yelavich (2025), the friction between artisanal sensibility and technological systems constitutes a productive space for experimentation and innovation. The material resistance of artisanal practices combined with digital technologies generates new epistemological possibilities for design. Ultimately, the integration of technologies is not intended to replace the artisanal processes but to function in a complementary manner, maintaining human interaction in decision-making, quality assessment, and aesthetic expression (European Crafts Alliance and Ohayo Brand Curation S.L. 2024). The emergence of digital tools, particularly AI, requires critical reflection on the creative authorship, appropriation, and the preservation of the singularity of the artisanal gesture (Caires 2025; Chandrasekera et al. 2025). In fashion design and textile craft, this reflection becomes particularly pertinent, as digital processes tend to obscure material, physical, human, and environmental layers, reinforcing the need to balance the preservation of tradition with technological innovation (Sohoni and Kothari 2024).

Thus, the digital turn in fashion design should be understood not merely as technical innovation but as a field of negotiation between efficiency, creativity, and ethical-cultural responsibility, in which the concept of a “dynamic tradition” supports the continuity of artisanal heritage while enabling a new generation of designers to integrate and reinterpret textile ancestries (Kofler and Walder 2024).

In response to the first research question proposed in this study— “How can a synthesis between ancestral textile knowledge and digital design be fostered to strengthen ICH and stimulate hybrid creative languages in fashion design?” —this section proposes overcoming the historically constructed opposition between craft and technology in fashion design, proposing instead a symbiotic approach in which digital technologies act as mediators of intangible textile cultural heritage. Rather than framing digitalization as a threat to authenticity or a replacement of ancestral knowledge, this argument contends that digital technologies can play an active role in documenting, transmitting, reinterpreting, and sustaining traditional textile practices within contemporary contexts.

Recent literature has highlighted this paradigm shift by recognizing that digital processes, when integrated in a critical and situated manner, do not negate artisanal knowledge but rather contribute to its translation into new systems of creation and production. Authors such as Casciani and Vandi (2022), Caires (2025), Veerman (2024), and Kofler and Walder (2024) emphasize that technological mediation makes tacit knowledge visible, supports collaborative processes, and expands the possibilities of material

experimentation, thereby establishing a hybrid field where tradition and innovation coexist. In this sense, the four cases presented in this section—all developed within the Portuguese context—are not intended as isolated examples but as situated manifestations of this symbiosis, demonstrating how digital technology can function as an interface between cultural memory, artisanal practice, and contemporary fashion design, in alignment with the methodological and territorial framework defined in this study. Their analysis follows the four interpretive categories outlined in the methodological framework, allowing each case to be positioned within a coherent analytical system rather than compared descriptively.

Casa do Risco de Felgueiras

This case is a consolidated example of the application of digital technologies to safeguard and enhance regional textile heritage. Selected for its direct engagement with the preservation and transmission of ancestral embroidery practices from the Terra de Sousa, it illustrates the articulation between textile cultural heritage and digital mediation within an institutional framework dedicated to craft continuity.

Within the analytical categories guiding this study, the case is primarily positioned at the intersection of (1) textile heritage and ancestral knowledge and (2) digital mediation of craft practices, while also addressing (3) educational and cultural implications through its role in transmission and training. Established to document, teach, and transmit the embroidery of the Terra de Sousa, the institution recognized early that the valorization of this ancestral know-how required revising its production processes, particularly in response to contemporary demands for quality, precision, and reproducibility.

In this context, digital technologies are mobilized not as substitutes for artisanal practice but as instruments for improving accuracy, continuity, and preservation in embroidery production. The introduction of technologies such as scanners, plotters, and graphic software enabled the overcoming of limitations associated with traditional methods for transferring designs onto fabric, reducing distortions that compromised the quality of the final embroidery (Pires 2006).

Beyond technical improvement, these tools also support processes of cultural preservation by enabling the recovery and reinterpretation of fragile historical patterns. They further facilitate the creation of a systematized digital archive, and allow innovation through recombination of existing motifs, thereby reinforcing the continuity of the ICH associated with regional embroidery. In analytical terms, the case shows how digital mediation in heritage institutions supports the stabilization and reactivation of textile knowledge without displacing its artisanal foundations.

Programa Nacional Saber Fazer

At an institutional scale, this program frames the use of digital technologies as part of a broader strategy for the valorization of traditional arts in Portugal. Selected for its relevance as a public governance initiative operating at the intersection of cultural heritage, training, and economic support, it illustrates how heritage policies engage with technological mediation in contemporary contexts.

Within the analytical categories guiding this study, the case is primarily positioned within the “educational and cultural implications” category, while also intersecting with the “digital mediation of craft practices” category, as it operates through documentation, training, and knowledge-transfer infrastructures supported by digital tools.

The creation of support infrastructures, such as technological centers and training programs, fosters the intergenerational transmission of textile knowledge and its adaptation to new productive contexts, in which technology acts as a mediator between tradition, sustainability, and innovation. Consequently, the program operates as a system-level mechanism of heritage governance, in which digital technology structures process documentation, training, and knowledge circulation, ensuring the continuity and contemporary activation of craft practices within public policy frameworks (Programa Saber Fazer 2025).

Susana Bettencourt

This case is selected as an authorial design practice that integrates digital technologies into knitwear while maintaining a sustained engagement with textile heritage. It illustrates the intersection between craft knowledge, digital mediation, and experimental fashion design. Within the analytical categories guiding this study, the case is positioned across (1) textile heritage and ancestral knowledge, through crochet, lacemaking, and embroidery; (2) digital mediation of craft practices, using AI; and (3) hybridization between manual and digital processes, combining handicraft and computational design workflows.

The designer’s practice maintains close connections with ancestral textile knowledge, both through familial and territorial ties and through the systematic exploration of traditional techniques such as crochet, lacemaking, and embroidery, frequently incorporated into her collections. This relationship with textile craft is articulated with a practice centered on the full production of knitwear, from yarn to finished garment, combining technical mastery of knitting with an authorial approach oriented toward formal experimentation and critical reflection on contemporary issues (Susana Bettencourt 2024). The collection *Weird It Out* (2025) was developed within the framework of a scientific research project that resulted in the creation and application of the Upcycling Knitwear (UpK) framework (Lopes et al. 2025), which integrates AI into knitwear design processes focused on the valorization of surplus materials and the reduction of waste through upcycling. The model organizes the process into stages that

articulate the analysis of surplus materials, the study of trends and brand identity, the generation of visual concepts through image creation tools such as Midjourney, and the human curation of digital outputs. In this context, AI functions as a mediating layer within a hybrid system, between technical knitting knowledge, material memory of yarns and jacquards, visual experimentation, and production processes. It supports material strategies, reduces waste, and extends textile knowledge within a digital environment.

Overall, the case illustrates AI as part of a hybrid craft–technology system, rather than as an autonomous creative force, reinforcing its role within the contemporary symbiosis between digital design and textile heritage.

Paatiff by José Sobral

This brand is selected as a design practice that integrates AI into the conceptual and procedural development of fashion design. It illustrates how AI can operate beyond tool-based applications, functioning instead within a systemic design logic that connects ideation, prototyping, and material realization.

Within the analytical categories guiding this study, the case is positioned across (1) hybridization between manual and digital processes, (2) digital mediation of design practices through AI-based systems, and (3) educational and cultural implications, as it operates through collaborative and process-oriented design frameworks.

AI is incorporated as methodological support for the formal, structural, and material investigation of garments, operating as a mediator between ideation, visualization, and materialization (ModaLisboa 2023). The brand's participation in the first AI Fashion Week (New York) demonstrated its use in reinterpreting clothing archetypes and exploring contemporary visual languages while maintaining connections to cultural memory.

This approach was further developed in collaboration with Lion of Porches at ModaLisboa (2024), where digital tools structured early design stages through shared references, wearability parameters, and virtual prototyping (ModaLisboa 2024). The use of materials such as cotton and denim anchors the process in utilitarian textile traditions, while the transition from digital to physical production reinforces the role of human craftsmanship in realization. Thus, AI functions as a systemic mediating interface rather than a creative agent, structuring relations between material tradition, functional design logic, and digital experimentation. Overall, the case illustrates a model of systemic mediation in which hybrid design processes are organized through the interaction of human expertise, material knowledge, and computational tools.

The analysis of the cases discussed in this study demonstrates that the integration of digital technologies into fashion design does not imply the replacement of ancestral knowledge. On the contrary, technology tends to operate as a mechanism of mediation between cultural memory and design innovation. As argued by Yelavich (2025), when craft,

design, and digital technology are critically integrated, they collectively contribute to understanding design as part of the processes through which cultural and material worlds are constructed. Across different scales—institutional, authorial, and collaborative—digital technology emerges as an interface between cultural memory, artisanal practice, materiality, and formal innovation, contributing to the continuity and reconfiguration of intangible textile cultural heritage. The consolidation of this symbiotic approach between tradition and technology thus presents both challenges and opportunities within the field of fashion design education, particularly regarding the integration of pedagogical methodologies capable of articulating artisanal knowledge, technological literacy, and critical thinking—an issue addressed in the following section.

Implications for Fashion Design Education

As the continuity of textile knowledge as ICH depends on its capacity to engage with contemporary contexts, this section addresses the second guiding question of this study: “How can fashion design education integrate, in a critical and culturally sensitive manner, both manual and digital competencies?” The analysis of the cases demonstrates that the integration of digital technologies into fashion design does not replace ancestral knowledge. On the contrary, technologies operate as mechanisms of mediation between cultural memory and innovation, enabling traditional practices to be reinterpreted within new creative and productive contexts. Within this framework, fashion design education is a strategic space for articulating artisanal know-how, material experimentation, and digital technologies, conceived not as opposing spheres but as complementary fields of learning, creation, and critical reflection.

According to the literature and guidelines established by UNESCO (2003), the preservation of ICH is intrinsically linked to educational processes capable of integrating artisanal knowledge into contemporary systems of production, research, and experimentation (Caires 2025; Casciani and Vandi 2022; Cesário 2025; Di Sarno and Liberti 2025; European Crafts Alliance and Ohayo Brand Curation S.L. 2024; Pentescu 2023; Sohoni and Kothari 2024; Veerman 2024). In this context, fashion design education emerges as a privileged framework for the codification, interpretation, and critical activation of such knowledge, reinforcing its symbolic, social, and economic value, as well as its capacity to adapt to new cultural and technological contexts (Casciani and Vandi 2022). This perspective shifts the notion of preservation from a static understanding to a logic of dynamic continuity, in which heritage is conceived as a living and constantly evolving process.

From this standpoint, the literature highlights the need for pedagogical methodologies that prioritize experiential and relational learning, in which knowledge emerges from direct interaction with materials, techniques, territories, and cultural narratives. Research conducted on the island of Madeira, involving embroidery and wickerwork techniques and

the participation of students in processes of participant observation and co-creation, demonstrated that the most significant pedagogical impact lies not only in the acquisition of isolated technical solutions but in the transformation of students' perceptions, leading them to recognize craft as a creative asset capable of technological and aesthetic reinterpretation (Cesário 2025). These findings reinforce the relevance of educational models that bring together students, artisans, and territories, enabling ancestral knowledge to be understood as a living resource for innovation in contemporary design.

Based on these theoretical and empirical premises, this study proposes a pedagogical framework structured around four fundamental pillars of learning, aimed at training designers who can engage critically and with cultural awareness at the intersection of tradition and technology:

- **First Pillar—Experiential Learning, Grounded in the Principle of “Learning by Doing”:** This model emphasizes that knowledge emerges from direct, physical engagement with materials, techniques, and territories. Material experimentation enables students to develop a sensory and contextual understanding of artisanal processes, recognizing the value of gesture, time, and embodied practice within ancestral knowledge. This form of learning reinforces the cultural and territorial dimensions of fashion design, allowing designers to understand artisanal production systems not only as techniques but as expressions of cultural identities and social relations (Cesário 2025).
- **Second Pillar—Hybrid Approaches Based on Collaborative and Intergenerational Practices:** Within this framework, fashion design education should promote dialogue between master artisans and new generations of designers through methodologies inspired by ethnographic practices, co-design processes, and interdisciplinary collaboration (Cesário 2025; Casciani and Vandi 2022). Such interaction strengthens the connections between tradition and innovation, ensuring that cultural heritage is understood as a dynamic and evolving process, in which artisanal knowledge is continuously reinterpreted in response to social, cultural, and technological transformations.
- **Third Pillar—Critical Integration of Digital Technologies, in Which the Designer Assumes the Role of Mediator and Curator of Algorithmic Systems:** In this context, the incorporation of digital technologies, particularly generative AI (GenAI) systems, should be understood as an extension of pedagogical and creative processes, rather than a rupture with materiality. Studies by Di Sarno and Liberti (2025) demonstrate that GenAI tools enable the creation of digital visual scenarios that can replace physical prototypes in early design stages, accelerating experimentation cycles, facilitating collaboration between designers and industry, and reducing the environmental impact associated with premature production. When critically integrated, these technologies expand the field of ideation without compromising the centrality of tacit knowledge and manual know-how

(Veerman 2024). Within this framework, creativity emerges from the interaction between humans and technology, with the designer responsible for interpreting, selecting, and refining generated outputs (Di Sarno and Liberti 2025).

- Fourth Pillar—Development of Cultural Intelligence and Critical Digital Fluency: The increasing integration of AI into fashion design education raises significant pedagogical challenges, including the risk of aesthetic homogenization, premature fixation on algorithmic solutions, and the weakening of experimental processes essential to creative development (Chandrasekera et al. 2025). These risks are particularly acute in cultural and artisanal contexts, where intuition, error, and material experimentation play a structuring role in learning processes (Chandrasekera et al. 2025; Lee 2025). In this regard, Lee (2025) proposes the concept of “cultural intelligence in the digital age,” arguing that design education should foster a critical digital fluency capable of integrating technological competencies, cultural sensitivity, and ethical reflection.

Within this pedagogical approach, design assumes a central role as a practice of interpreting and codifying ICH, contributing to the development of innovative educational devices such as interactive narratives, immersive experiences, and digital prototyping practices (European Crafts Alliance and Ohayo Brand Curation S.L. 2024; Lee 2025). These approaches foster the development of cultural empathy and deepen the understanding of artisanal realities, while reinforcing co-design processes as forms of cultural mediation between bearers of traditional knowledge and new generations of designers (Cesário 2025).

In this way, the articulation between artisanal knowledge and digital technologies requires educational models capable of integrating different forms of technical, cultural, scientific, and humanistic knowledge. The incorporation of training materials, educational kits, intergenerational experiences, and intersectoral programs may contribute to the creation of resilient creative ecosystems between craft and fashion, simultaneously strengthening the cultural, social, and economic sustainability of these production systems (Casciani and Vandi 2022; Kofler and Walder 2024).

In this sense, cultural sustainability emerges as a structuring axis of fashion design education, aligned with a transdisciplinary vision of education that articulates practical, humanistic, and scientific knowledge in response to complex challenges, as advocated by Morin (2015). The ultimate objective is to educate designers capable of navigating critically and sensitively between hand and machine, recognizing the value of artisanal traditions while constructing new possibilities for the future of fashion design.

Discussion

The case analysis allows for a deeper understanding of the conceptual transition advanced throughout this article: from the historically constructed opposition between craft and

technology toward a logic of symbiosis mediated by design. The examples demonstrate that the integration of digital technologies into fashion design does not entail the replacement of ancestral textile knowledge but rather its reconfiguration within hybrid ecosystems of creation, production, and cultural transmission (Casciani and Vandi 2022; Kofler and Walder 2024).

In the case of Casa do Risco de Felgueiras, technology operates primarily as a mechanism for safeguarding and enhancing ICH. The digitization of designs, the creation of systematized archives, and the improvement of graphic transfer processes for embroidery reveal a form of technical mediation that responds to contemporary demands for precision and to the need to preserve the formal and symbolic integrity of traditional embroidery. This case exemplifies the capacity of design and digital technologies to render tacit knowledge visible and transmissible without culturally decontextualizing it, as argued by Casciani and Vandi (2022). Innovation thus emerges from the continuity of a situated artisanal system, rather than from its disruption.

The Programa Nacional Saber Fazer extends this logic to an institutional scale, demonstrating how public policies can structure favorable environments for the articulation between tradition, technology, and economic sustainability. By recognizing craft as a dynamic, productive sector capable of technological innovation, the program reinforces the notion of heritage as a creative process, aligned with UNESCO (2003). Within this framework, technology functions as a mediator between intergenerational transmission, professional training, and integration into contemporary value chains, aligning with the perspectives of dynamic tradition discussed by Kofler and Walder (2024) and the European Crafts Alliance Report (2024).

At an authorial and experimental level, the case of the Susana Bettencourt brand illustrates how AI can be integrated into design processes deeply rooted in the materiality and technical knowledge of knitwear. In the context of the *Weird It Out* (2025) collection, the application of the UpK framework enabled the incorporation of GenAI into the knitwear design process, articulating digital ideation, human curation, and technical materialization. This approach was oriented toward the creative reinterpretation of surplus materials and the optimization of available resources, demonstrating how technology can support circular economy strategies without compromising the material and artisanal identity of the brand (Lopes et al. 2025). The use of GenAI tools thus functioned as a visual and conceptual catalyst, engaging with the material memory of yarns, jacquards, and manual techniques, while maintaining the designer's critical judgment and tacit knowledge as central elements of the creative process, as discussed by Chandrasekera et al. (2025), Di Sarno and Liberti (2025), and Kofler and Walder (2024).

Complementarily, the case of Paatiff, particularly its collaboration with Lion of Porches, demonstrates how AI can mediate processes of formal, structural, and material investigation in contemporary fashion design. The articulation between algorithmic visualization, virtual prototyping, and physical materialization reveals a continuity of productive knowledge associated with workwear, particularly in terms of functionality, durability, and technical

skill in garment construction. The selection of materials such as cotton and denim anchors digital innovation in historical practices of utilitarian clothing, reinforcing the idea that technology does not dissolve materiality but rather critically reinterprets it, as noted by Caires (2025), Chandrasekera et al. (2025), and Lee (2025).

Taken together, the four cases reveal different modalities of technological mediation—documentary, institutional, experimental, and methodological—that converge in a shared logic of mediation between cultural memory, artisanal practice, and innovation in fashion design. This observation reinforces the theoretical arguments presented here, according to which digital processes, when critically and contextually integrated, contribute to the translation of ancestral textile knowledge into new creative and productive languages (Kofler and Walder 2024; Veerman 2024).

In this context, there is a need for integrative models capable of articulating these tensions while operationalizing the relationship between craft knowledge and digital technologies.

To synthesize the theoretical reflections and empirical evidence derived from the cases, the “Symbiosis of Knowledge” framework (Figure 1) is proposed. This visual model operationalizes the transition from a binary opposition to a symbiotic logic, positioning the designer as a mediator, translator, and curator of cultural knowledge, operating across territories, communities, materials, and digital systems (Casciani and Vandi 2022). The framework illustrates a non-linear circular flow that integrates ancestral materiality with digital virtualization through the four educational strategies outlined in the “Implications for Fashion Design Education” section: (1) experiential learning, (2) hybrid approaches, (3) digital integration, and (4) cultural intelligence.



Figure 1: Symbiosis of Knowledge Framework

When applied to the four cases, the framework demonstrates its analytical value by revealing differentiated configurations of mediation:

- Casa do Risco de Felgueiras is primarily situated in Sensory Immersion (dimension 1) and Digital Translation (dimension 2), where heritage preservation and digitization processes dominate.
- Programa Nacional Saber Fazer operates mainly at the level of Critical Reflection (dimension 4), functioning as institutional mediation and governance of heritage transmission.
- Susana Bettencourt engages all four dimensions, particularly Digital Translation (dimension 2), Hybrid Prototyping (dimension 3), and Critical Reflection (dimension 4), where AI is embedded in materially grounded experimentation.
- Paatiff concentrates on Digital Translation (dimension 2) and Hybrid Prototyping (dimension 3), with a strong systemic orientation in which AI structures end-to-end design workflows.

This mapping evidences that the framework does not describe a linear model of digital transformation but a set of differentiated symbiotic configurations shaped by context.

Despite its analytical and operational potential, the implementation of such symbiotic models remains uneven and structurally constrained. As discussed throughout the literature mobilized in this article, limited access to digital infrastructures, high adoption costs, unequal resource distribution, and gaps in technical training continue to restrict their broader applicability (European Crafts Alliance and Ohayo Brand Curation S.L. 2024). At the same time, deeper concerns emerge regarding the potential marginalization of traditional competencies and technical knowledge, raising ethical concerns alongside issues of authenticity and practice. In particular, the increasing integration of AI introduces the risk that algorithmic decisions may not align with historically grounded intentions, potentially reshaping cultural narratives to privilege technical coherence over cultural authenticity (Caires 2025; Schulz and Ferreira da Cunha 2026). In educational contexts, rigid curricula and insufficient integration between craft-based learning and digital competencies further hinder consolidation (Casciani and Vandi 2022; Lee 2025; Wang and Alli 2025; Yelavich 2025). A persistent challenge, therefore, lies in balancing technological adoption with the need to contextualize its material and environmental implications, while preserving meaningful aesthetic experience and cultural integrity. These conditions indicate that the transition toward craft–technology symbiosis is not only conceptual but systemic, requiring coordinated institutional, economic, pedagogical, and ethical responses.

The operationalization of these four pillars presupposes curricular restructuring through “Textile Co-creation Laboratories,” in which the pedagogical sequence is not linear but cyclical. A practical four-stage method is proposed: (1) Sensory Immersion, focused on direct

manual learning with artisans to understand material resistance and logic; (2) Digital Translation, in which manual gestures are captured or reinterpreted through CAD or GenAI tools to explore variations not possible in physical media; (3) Hybrid Prototyping, employing digital fabrication methods, such as laser cutting or 3D printing, to construct bases that will subsequently receive ancestral manual intervention; and (4) Critical Reflection, evaluating how technology has altered the perception of the cultural value of the final object. This cycle ensures that algorithms do not dictate form; instead, they function as tools that amplify artisanal intelligence.

In doing so, this model demonstrates how technological mediation functions not as a substitute but as a catalyst for cultural continuity, ensuring that manual practice and digital technologies coexist within a dynamic equilibrium that sustains intangible heritage within contemporary fashion systems. This positioning confirms the emergence of a hybrid professional profile. It points directly to the educational challenges addressed in the following section (Implications for fashion design education), in which fashion design education is framed as a strategic space for ensuring the critical and culturally sensitive continuity of textile knowledge as ICH.

Conclusion and Future Perspectives

This article demonstrated that the historically constructed opposition between craft and technology in fashion design is insufficient for understanding contemporary practices in the field. In its place, a logic of symbiosis emerges, in which digital technologies act as mediators between cultural memory, artisanal practice, and design innovation. This approach enables textile heritage to be understood not as a static legacy but as a living process, continuously reinterpreted through contemporary languages, materials, and tools.

The cases analyzed reveal that such technological mediation may assume institutional, political, authorial, and collaborative configurations, converging on a common premise: technology is not antagonist to cultural knowledge but an opportunity for its valorization, reinterpretation, and continuity. Digitalization, AI, and computational visualization processes demonstrate the potential to support the safeguarding of textile heritage, the empowerment of artisanal communities, and the sustainable development of local economies, provided that the implementation of these tools considers economic and technical accessibility barriers that continue to distance many bearers of traditional knowledge from digital innovation.

Within the educational domain, fashion design education emerges as a strategic space for articulating tradition and innovation. The critical integration of digital tools, combined with experimental, situated, and collaborative methodologies, makes it possible to preserve the centrality of manual practice in the training of designers, while expanding the field of creative experimentation. The operationalization of this symbiosis through cyclical pedagogical

models, integrating sensory immersion, digital translation, and hybrid prototyping, proves fundamental in ensuring that algorithms function as amplifiers, rather than substitutes, of manual intelligence. In this sense, the importance of manual practices is reaffirmed as the foundation of material sensibility, critical reflection, and cultural responsibility, positioning the designer as a mediator and translator of ICH knowledge.

Future perspectives point to the need to deepen empirical studies that document hybrid projects developed between designers and artisanal communities, assessing their impact on the transmission of knowledge and on cultural and economic sustainability. At the same time, it becomes relevant to design and test hybrid methodologies in fashion design education capable of integrating ethnography, co-design, material experimentation, and digital technologies in a culturally situated and ethically informed manner. In this regard, the convergence between artisanal knowledge, design, and digital technologies may be understood as part of a broader process of cultural construction. As suggested by Yelavich (2025), when these dimensions are critically articulated, design moves beyond being merely an instrument of production and becomes a relational practice capable of proposing new conditions and outcomes for creative work.

In summary, this article contributes to the contemporary debate by positioning fashion design as a field of mediation between memory, materiality, and technology. By recognizing textile heritage as a living and relational process and education as central to its continuity, it advocates a vision for the future of fashion in which hand and algorithm, as well as tradition and innovation, coexist within culturally conscious and socially responsible creative practices that use technology to regenerate social and identity fabrics.

Finally, it is important to acknowledge the limitations of this study. Its qualitative and interpretive nature—together with the limited number of case studies and the study's geographically bounded focus on Portugal—constrains the generalizability of the findings. Nevertheless, the selected cases are conceived as theoretically illustrative and analytically productive, offering insight into broader relational dynamics between textile heritage, digital technologies, and fashion design education.¹

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Informed Consent

The authors declare that informed consent was not required as there were no human participants involved.

Conflict of Interest

The authors declare that there is no conflict of interest.

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