Learning from Hybrid Craft: Investigating and Reflecting on Innovating and Enlivening Traditional Craft through Literature Review

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ABSTRACT

The key to preserving traditional crafts lies in living transmission, which is inseparable from sustaining artistic production, audience consumption, and progressive innovation with the physical media. As HCI researchers, we focus on the hybrid crafts field, which involves numerous cross-disciplinary integration cases between traditional craftsmanship and digital technology at the physical level, providing inspiration for innovating and enlivening traditional crafts. We conducted a multi-perspective review of 85 hybrid craft articles related to traditional crafts over the past decade, considering aspects such as craft categories, digital technology, target users, and research areas. Through reflection, we propose a design framework for fostering innovation and revitalizing traditional crafts. This paper aims to offer insight into the innovation and enlivenment of traditional crafts through a hybrid craft perspective while also serving as a first review of the hybrid craft field from the traditional craftsmanship perspective.

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CCS CONCEPTS

• **Human-centered computing → HCI theory, concepts and models**.

KEYWORDS

traditional craft innovation; culture heritage, hybrid craft; literature review

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1 INTRODUCTION

The traditional craft carries the memory of the times, reflects the aesthetics and lifestyles of specific eras, and is an important component of human culture. These crafts once shone brightly in history, supplying aesthetics and practicality to people's lives. However, the advancement of technology and changes in production methods have altered the social environment in which traditional craftsmanship can thrive, leading to the gradual decline of traditional crafts and the loss of intangible cultural heritage. The preservation, inheritance, and innovation of traditional craftsmanship have also become topics of concern for various sectors of society [12, 54, 76].

Digital technology has become an important means of preserving traditional craft. Compared to museum-style "static preservation" through digital documentation and presentation, enabling traditional craftsmanship to undergo "living transmission" is a better way of protection [32, 50, 76]. Living transmission means that through continuous creative practice by people, traditional craftsmanship can progress with the current cultural and social environment to actualize the inheritance of tradition while advancing with the times, thereby revitalizing it in modern life [76, 89].

The living transmission of traditional craftsmanship is inseparable from innovating and enlivening them through continuous production and transmission of skills and knowledge involved in craftsmanship onto others, rather than simply converting it into digital form [50]. As HCI researchers, we set our sights on the "hybrid craft" field, also known as "digital craft". Hybrid craft is a broad concept characterized by incorporating physical and digital elements. It could be manifested in the raw materials, crafting process, techniques and tools, and the final craft product [17, 25, 35, 82, 85]. In the hybrid craft field, some HCI researchers engaged in the cross-disciplinary innovation of digital design and fabrication with traditional craftsmanship at the physical level, resulting in numerous instances of innovation. Some studies adopted the approach to merging traditional art and craftsmanship with modern design and technology as a means to preserve tradition and cultural diversity [13, 23, 35]. Other researchers were inspired by traditional craftsmanship to bring about new HCI innovations by integrating the wealth of traditional materials, techniques, and cultural elements with digitally responsive components [19, 28, 41].

The above cases show the potential for the hybrid craft field to inspire HCI researchers to innovate and enliven traditional crafts. In this article, given the systematic and comprehensive advantages that literature reviews bring to domain knowledge [91], we hope to explore how traditional crafts can be revitalized in contemporary times through the hybrid craft method by literature review. Meanwhile, we have found that research on hybrid craft is highly varied in aspects such as research objectives and craft types. Hence, there is a pressing need to develop a systematic way of organizing literature on hybrid craft. Therefore, this paper is the first research on how to innovate and enliven traditional crafts through the hybrid craft method and serves as the first literature review of hybrid craft from a traditional craftsmanship perspective.

Given the research opportunities above, we investigate and reflect on innovating and enlivening traditional crafts through the literature review of 85 hybrid craft articles from high-impact HCI publications in the past decade. The research path is shown in Figure 1, leading to the following research content and contributions:

(1) This paper provides an initial understanding of how traditional crafts are innovated and revitalized through a hybrid craft approach. Meanwhile, it also presents an initial literature review of the hybrid craft domain from the standpoint of traditional craftsmanship.

(2) We reviewed hybrid craft cases related to traditional crafts from multiple perspectives, including craft categories, digital technology usage, and target users, providing specific and straightforward inspiration for the innovation and enlivenment of traditional crafts.

(3) Through qualitative and quantitative methods, we summarized five research areas related to traditional crafts within the hybrid craft field, providing directional references and inspiration for innovating and enlivening traditional crafts.

(4) Upon reflecting on the entire content, we propose a design framework for innovating and enlivening traditional craft, consisting of three layers: value judgment, artifact innovation, and people involvement. We hope this framework can provide guidance at the methodological level.

2 BACKGROUND AND RELATED WORK

From pre-industrial to post-industrial society, the relationship between traditional craftsmanship and technology has shown a trend of integration, separation, and integration once again [90]. Traditional craft has undergone new advancements in the digital age by merging with digital technologies. The discussion about the relationship between traditional craftsmanship and digital technology has also captured the attention of HCI researchers. For example, in 2016, a workshop was organized during the DIS conference, highlighting that digital technology has expanded the potential of existing expressive mediums [34]. However, the integration of digital technology with craftsmanship is not easy. The workshop aimed to explore strategies to overcome tensions between digital technology and craftsmanship and focused on applying HCI principles to craftsmanship. In 2019, a workshop at CHI aimed to define the academic and practical field around craft and HCI and to discuss the many ways computational technologies are being developed around craft [67].

Integrating traditional craftsmanship and digital technology at a physical level is also referred to as hybrid craft or digital craft [20, 23, 80]. Different scholars have different interpretations of its definition. For example, Connie Golsteijn sees hybrid craft as a new form of everyday manual craft practice where physical material and digital technology are increasingly integrated, offering new opportunities for contemporary craft creation. Daily life holds extensive potential for hybrid craft, providing rich media that can be fused with digital elements in the creative process and promoting the emergence of new craft forms [25]. Amit Zoran created a series of studies and practices that combine traditional crafts such as ceramics, bamboo weaving, and woodworking with digital technology. He encapsulates hybrid craft as combining digital design and fabrication with traditional craftsmanship [97]. Ye Tao defines digital craft as the integration of digital technology with the characteristics of traditional craftsmanship. It also refers to the manifestation of traditional craft characteristics in the digital age, specifically within everyday creative practices geared towards digital design and fabrication [79].

In the hybrid craft field, numerous artists, designers, makers, and artisans have incorporated digital technology into their creations, expanding traditional craft's creative possibilities. For instance, creators have introduced digital technologies like 3D printing and laser cutting into traditional craft production, lowering the costs of trial and error and reducing the learning curve [13, 80]. It allows enthusiasts without specialized skills to create personalized craft pieces. By combining digital materials, electronic components, computer-aided design, and fabrication techniques with traditional craftsmanship, practitioners can open up new creative spaces and produce more expressive works. Examples include parametric metal art based on growth logic [90] and interactive silverware with functional features [82].

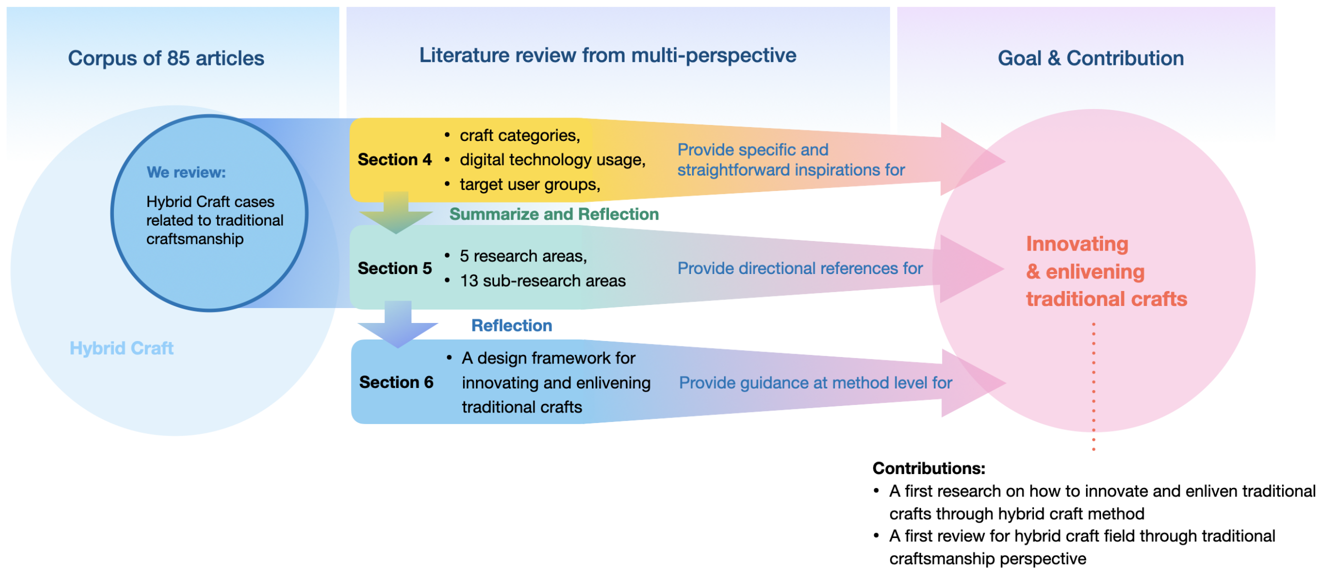

Figure 1: The research path of this paper. We investigate and reflect on how to innovate and enliven traditional craft by reviewing hybrid craft cases related to traditional craftsmanship.

We have witnessed the value of the above efforts in innovation and revitalizing traditional crafts. These efforts help bridge the aesthetic gap between traditional crafts and contemporary audiences, offering opportunities for modern users to participate in craft creation. This resurgence of interest allows traditional crafts to return to the public's view and become relevant to everyday life, circulating through innovation and igniting new vitality in real-world contexts. Considering the systematic and comprehensive advantages of the literature review, we aim to review hybrid craft cases related to traditional craftsmanship, thereby investigating and reflecting on the innovation and enlivenment of traditional craft. Simultaneously, while there are numerous research cases within the hybrid craft field, their themes and objectives are somewhat scattered, primarily focusing on individual cases within specific craft domains(e.g., [31, 78]) or the analysis of related concepts [20, 60]. This lack of a systematic overview prompted the need for this article, which also offers a perspective on hybrid craft from the lens of traditional craftsmanship, filling a gap in the existing research.

3 METHODOLOGY

3.1 Literature Selection

In the HCI field, research on hybrid craft mainly appears in three categories of conferences: CHI, TEI, and DIS. There are also some references in other high-impact publications such as CSCW, Ubicomp, UIST, and TOCHI. Therefore, we have selected our search scope to include CHI, TEI, DIS, CSCW, Ubicomp, UIST, and TOCHI, aiming to acquire high-quality knowledge from reputable publications. Considering the timeliness of the study, we chose literature from the last decade to build the corpus (Jan 2013 to June 2023).

Keywords Match: 1) Hybrid craft and the related expressions: "hybrid craft", "digital craft". 2) Expressions related to traditional craft: "traditional craft", "traditional craftsmanship", "craft", "Intangible culture heritage", "craftsmanship", "handicraft". 3) Technology-related expressions: "technology", "digital technology".

Selection Criteria: Our primary goal is to identify research cases related to traditional crafts within the context of hybrid crafts, with the following criteria:

(1) In defining traditional crafts, articles should be relevant to at least one of the following criteria: a) Traditional handicraft skills and arts and crafts, such as weaving, sewing, carving, ceramics, embroidery, glasswork, metalwork, etc. These arts and crafts often originate from traditional societies in the pre-industrial era, and as such, we refer to them as traditional. Moreover, they frequently establish themselves as specialized disciplines within art academies. It is important to note that tradition within traditional arts and crafts does not imply being fixed to a specific historical period. The inheritance of traditional craft is fluid, born in traditional societies but evolving with new characteristics as times change. b) Traditional crafts associated with history, culture, or ethnic characteristics, or intangible cultural heritage handicrafts, such as Japanese lacquerware or Chinese paper cutting.

(2) For digital technology usage, we focus on the technologies employed in the hybrid craft field. We remove the literature on "museum-type static preservation", mainly related to digital documentation and presentation technologies, such as VR museums for traditional craft.

(3) we removed workshop papers because they only present workshop topics without specific innovative practices or perspectives. However, we kept the extended abstract and late-breaking works. Although these papers are not complete and are only preliminary explorations, they are enough to inspire the readers and facilitate their reflections.

According to the criteria above, three researchers divided the articles from CHI, TEI, DIS, CSCW, Ubicomp, UIST, and TOCHI into batches for article screening. They conducted a preliminary review of the titles and abstracts of the articles and obtained a total of 99 articles. Subsequently, the researchers convened a meeting to exchange opinions and reached a consensus on the article selection. Ultimately, 85 articles were chosen to form the corpus for this paper.

3.2 Literature Analysis Process

This article aims to explore how hybrid craft methods can inspire innovation and enlivenment in traditional crafts by reviewing cases of traditional crafts within hybrid contexts. We aim to focus on the following aspects across 85 articles:

- Craft Perspective: We intend to understand various craft categories and their specific innovative approaches.
- Digital Technology Perspective: We aim to comprehend which technologies can empower innovation and revitalization in traditional crafts.
- People Perspective: People serve as the carriers of traditional craft inheritance and innovation. We are interested in identifying the target users who can benefit from innovative advancements in traditional crafts.
- Research Areas Perspective: We aspire to uncover the various research fields involved in cases of traditional crafts within hybrid contexts. This information can serve as a reference for directions in traditional craft innovation.

We analyze papers in both manual and statistical ways, including the following steps:

(1) Exploratory reading: Five researchers divided the 85 articles into batches, with each batch being read and analyzed independently by one researcher. During the exploratory reading phase, researchers needed to record the abstract and main content of the articles in an online shared spreadsheet. Once all the researchers completed their reading, a meeting was convened to discuss and exchange opinions on the recorded content to provide all researchers with a preliminary understanding of the 85 articles.

(2) In-depth reading: After gaining a preliminary understanding of the 85 articles, the researchers move on to the phase of in-depth reading. Researchers need to focus on the research questions, contributions, types of craft involved, use of digital technologies, target user groups, reflections on the humanistic aspects of the articles, and record these aspects in a shared spreadsheet. After all the researchers have completed their reading, a meeting is held to discuss and exchange opinions on the recorded content. The purpose is to ensure that all team members develop a profound understanding and reach a consensus regarding the abovementioned aspects in the 85 articles.

(3) Literature Coding: To distill the content of 85 articles into a succinct summary, each article underwent independent coding by five researchers, with a focus on the craft category, digital technology, and the target user group. Consensus meetings ensued, yielding nine craft category labels (see section 4.1), four digital technology labels (refer to section 4.2), and six target user group labels (outlined in section 4.3. Following this, the five researchers independently conducted open coding for research area labels, guided by research questions, article contributions, and the labels above. Consensus was achieved through collaborative meetings. For instance, articles emphasizing tools for crafting processes were labeled as "crafting process aids," while those highlighting interdisciplinary collaboration were designated as "collaborative collaboration of multiple roles." Articles addressing multiple themes received multiple labels, identifying 13 sub-research area labels (see section 5. In the final step, researchers performed a high-level thematic summarization. For example, both "crafting process aids" and "promoting crafting enjoyment" centered on the crafting process, leading to their classification under "enhancing crafting experience." This process culminated in the establishment of 5 research area labels.

(4) Research area correlation analysis: Based on the qualitative summary mentioned above, we also aim to conduct a quantitative analysis to enrich the findings of this research. We referred to the bibliometric approach adopted by Yao et al. in their smart home-related review study [91]. The following steps were carried out to identify the relationships and interdependencies of research areas.

Firstly, we performed one-hot encoding on all labels, which included 13 sub-research areas, six target user groups, four digital technologies, and nine craft categories. It resulted in a 32-dimensional feature matrix M for the articles.

Subsequently, the classical dimensionality reduction technique, Principal Component Analysis (PCA), was used to analyze the interdependence between research areas in the encoded data. It is important to note that PCA was not performed on the research areas but on the 32-dimensional features so that the latter were reduced to lower dimensional representations that could capture the characteristics of article data distribution; the former served as the articles' labels, marked as different colors in Figure 6. This figure was generated using the first two Principal Components (PCs), explaining 17.96% and 12.79% of variance[1] in M, respectively. It should be noted that the ratios were not high enough to explain all variances of the data, implying the limitation of quantitative analysis in this study, but it still offered insights into how articles differed.

Then, in Figure 6, we marked seven features most statistically correlated with the two PCs. The length of each feature indicated the magnitude of contribution to the variance of the data, whereas the angle between a pair of features represented their correlation coefficients[2]. Therefore, the distributions of features and research areas could be analyzed based on Figure 6.

4 ANALYSIS RESULTS FROM CRAFT, DIGITAL TECHNOLOGY, AND TARGET USER PERSPECTIVE

4.1 Craft Categories and Innovative Results

In this subsection, we summarized nine craft categories and their innovations, which will bring inspiration to innovating traditional crafts for practitioners in related fields. Figure 2 shows the count of craft categories sorted by the year of the publication.

[1]The higher the explained variance ratio by a component is, the better the component can illustrate the distribution of the original data.
[2]An angle of 90 degrees meant the two features were independent; an angle of 0 degrees (or 180) degrees meant the two features were perfectly positively (or negatively) correlated.

							Legend:	1	2~3	4~6	≥7
Craft Category	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Carpentry			1		1	1	1	1		1	
Traditional craft with local features		1	1		1	1	2	1	2	1	2
Ceramics				1	3		3			3	1
Textile	1	2	5	5	4	7	4	5	7	6	4
Papercraft	1				2	2			1	1	1
Glass									1		2
Metal craft					1						
Lacquer art						1		1			
Printmaking						1					

Figure 2: Count of craft categories sorted by the year of the publication. Note that each article may refer to multiple craft categories, causing the total number of craft category labels to be greater than 85.

4.1.1 *Textile.*

Textile has been the most extensively studied craft over the past decade, accounting for 53.19% of the articles. Textile includes weaving, knitting, clothing, and embroidery, covering a variety of user groups and application scenarios. Textiles use easily accessible and inexpensive materials involving various everyday items. They also have the advantage of close contact with the human body, making them highly promising for both input and output applications in the HCI field. Many studies utilize the flexible nature of weaving techniques to integrate circuits, electronic components, and fabric, transforming textiles from traditional craft into novel interactive interfaces and wearable devices [78].

Moreover, textiles’ unique soft and tactile nature can provide a memorable emotional experience. The softness of the material evokes feelings of gentleness and warmth [57], and the process of hand-weaving contributes to relaxation and meditation [26]. These qualities make textile-based digital making particularly suitable for vulnerable social groups, including the older adults, children, and disabled people. Among the seven articles focused on these vulnerable user groups, six employed textiles in their research. For instance, Muehlbradt et al. enabled people with disabilities to use their designed "stateful textiles" to record their daily behaviors. These "smart textiles" served as both input and output, presenting the data and self-tracking interactions, exploring alternative ways of data representation and self-tracking interactions [57].

4.1.2 *Ceramics.*

Articles related to ceramics innovation account for 11.7% of the total, focusing primarily on innovations in texture and form. For instance, facing the difficulty of starting slab-based ceramics, researchers have developed an open-source software called Slabforge [31]. This software facilitates the creation of templates, which are crucial for slab-based ceramics modeling, and enriches the creative space for shaping. 3D printing plays a significant role in expanding the expressiveness of ceramic art. By transforming ceramics from a manual craft to a digital craft, it becomes possible to create parameterized forms that are difficult to achieve by traditional handcrafting. One example is the "ListeningCups" project, which converts environmental sound data into G-code to produce a set of 3D-printed cups representing this data in a textural and tactile form [14].

Furthermore, even though rigid ceramics are less accommodating and challenging to integrate with circuits than textiles, one article takes a different approach. It demonstrates how the resist-blasting technique serves as a foundation for applying conductive ink to the complex three-dimensional surfaces of glazed ceramics, enabling interactive functionalities without compromising aesthetic appeal [93].

4.1.3 *Traditional craft with local features.*

12.77% of the articles refer to traditional crafts with local features, i.e., traditional crafts that are explicitly related to ethnic and regional cultural characteristics. These crafts come from six different countries and regions, including Hairy Monkey [51], Cantonese Porcelain [54], Bamboo weaving [23], and papercutting [51] from China; Joomchi from Korea [40], lithophanes from Lithuania [87]; lacquerware from Japan [33]; Ebru from Turkey [59]; and Ju/’hoans from African tribes [35]. These crafts have acquired new forms and applications by integrating digital technology, revitalizing their cultural significance. For example, combining 3D printing and CNC technology in Ju/’hoans digital making has become a bridge for cross-cultural exchanges [35].

What sets this category of crafts apart from others is the emphasis on culture what sets this category of crafts apart from others is the emphasis on cultural inheritance. For instance, in the article [54], participants used Cantonese Porcelain as the theme for creating lamps with the aid of digital technology. However, the final works made with cardboard through CNC cutting did not reflect the core characteristics of Cantonese Porcelain. As a result, they were not considered innovations by experts and inheritors of

Cantonese Porcelain because they lost the core material and production techniques of Cantonese Porcelain. This type of research often carries the mission and aspiration of preserving and inheriting culture. Over the past decade, except for 2013 and 2016, 1-2 articles have been published in this category each year, indicating that researchers in the HCI field have begun to bring local and ethnic cultures onto the international academic stage.

4.1.4 Carpentry. Articles related to carpentry innovation account for 6.38% of the total. Carpentry is a highly specialized field, and research in this area aims to use digital technology to lower entry barriers to carpentry practices and expand the richness of woodworking, particularly in joint design. For instance, Larsson et al. developed a wood joint manufacturing system called "Tsugite," which allows users with limited expertise in woodworking but basic digital fabrication skills to create components with complex wooden joints [44]. Perhaps due to the increasing integration of digital fabrication in contemporary carpentry, making it challenging to rely solely on traditional manual methods, some researchers have reflected on the relationship between traditional craftsmanship and digital technology through woodworking practices [10]. It also shows us the new opportunities and vitality that woodworking has gained through its application in HCI research.

4.1.5 Papercraft. 8.51% of the articles involve Papercraft innovation, including papercutting [51], lantern crafting [80], paper weaving [39, 95], paper sculpture [61], and paper-making [40]. The first two craft categories focus on providing digital assistance in crafting, enabling users who need more professional skills to create artwork independently. For example, "inforigami" utilizes digital technology to simplify the complex spatial imagination and hand-eye coordination required in traditional perforated boneless lantern crafting, streamlining the production process [80]. Liu et al. guide users in easily creating papercutting artworks using design software and light-guiding devices [51].

The latter three craft categories primarily explore integrating digital technology to create interactive interfaces and materials within the Papercraft product. For instance, Zhu et al. present "SkinPaper" [95], a fabrication approach that uses silicone-treated washi paper to weave lightweight fabric that facilitates on-body interactions easily. The researchers adopt techniques from paper weaving and basketry to create paper-woven structures that can conform to the body.

4.1.6 Glass, Lacquer art, Metal art, and Printmaking. Glass, Lacquer art, Metal art, and Printmaking are the four least studied categories, accounting for 6.28% of the total. We speculate that these crafts receive less attention from researchers due to the difficulty in obtaining materials, complex production processes, and a high level of specialization. Combining the unique characteristics of materials and techniques with digital technology to develop new interactive materials and interfaces is currently a direction of innovation that has been explored. For example, researchers have explored transforming glass fiber into pressure-sensitive resistors [1], incorporating circuits into colored glass to create interactive interfaces [22], adding circuits to lacquer art surfaces to enable interactive functions [33, 71], and utilizing the conductive properties of silverware to create sensors [82].

4.2 Digital Technology for Craft Innovation

In this subsection, we categorized digital technology that could be used for innovating traditional crafts into four types, for reference for related practitioners. Figure 3 shows the count of digital technology usage over the past ten years.

4.2.1 Digital Fabrication Technologies. Traditional craft involves numerous making behaviors. In our research, 38.8% of the articles introduced digital fabrication technologies into the traditional craft, thereby expanding people's making capabilities, especially enriching the two- and three-dimensional structures and forms.

Among these, the most widely used technology is 3D printing, accounting for 14.1% of the articles. Some researchers directly employed intricate 3D-printed components as parts of their crafts. For instance, Liu et al. used 3D printing to create complex and personalized scene designs for Chinese Hairy Monkey handicrafts [50], while Magrisso et al. employed 3D printing to produce parametrically designed connecting joints for woodworking crafts [55]. Some researchers utilized 3D printing to fabricate complex supports for textile weaving [13], bamboo weaving [23], punch needle embroidery [11], etc., ultimately achieving intricate and aesthetic fabric structures. Moreover, researchers also explored using existing 3D printing platforms to apply additive manufacturing on traditional materials, including ceramics [14], wood [84], paper [61], etc., or computer numerical control (CNC) platforms (4.7% of the articles apart from 3D printing) to apply subtractive manufacturing on traditional materials, including wood [10, 44], and ceramics [70].

Digital fabrication technologies are also utilized to produce two-dimensional surface patterns or components. 10.6% of the articles employed printers or plotters to arrange (via programming) materials on the surface of the craft product to produce intricate aesthetic appearances [29, 83, 88], apply conductive materials to create patterns with specific electronic functions [39, 61, 71], or produce assembly drawings of craft components to aid the making procedure [31, 45, 81]. 9.4% of the articles also used laser cutting or plotter cutting to fabricate components or textures with complex shapes or patterns in various crafts, including boneless lanterns [80], glazed ceramic ware [93], polarized light mosaics [73], bamboo weaving [23], eggshell jewelry [35], etc.

As for fabric-based crafts, researchers also explored using industrial manufacturing machines to create fabric crafts with intricate aesthetic textures or advanced functional structures, Among them, 5.9% articles utilized digital embroidery machines [2, 28, 30, 47, 58], 1.2% used digital looming machines [4], and 1.2% used digital knitting machines [3].

4.2.2 Design tools and software. In our research, 42.4% of the articles utilized software algorithms to assist in the design process of crafts. Computer-aided design (CAD) technology is the most widely used technology, accounting for 37.7% of the articles. This approach employs computational methods to design and simulate two- and three-dimensional graphics during the design procedure of the crafts, which serve as the leading guide for the subsequent digital fabrication processes in most cases. Some works directly utilized existing CAD tools like Adobe Illustrator or Rhino to aid in the digital design and fabrication process of the crafts [23, 35, 50, 71, 81, 93], while the majority of works developed customized algorithms to

Legend: 1 | 2~3 | 4~6 | ≥7

Craft Category	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Digital Fabrication Technologies			2	6	1	4	5	5	4	3	6
Design tools and software	1	1	2	2	2	4	3	5	5	4	7
Interactive materials and hardware	1	2	4	2	6	9	4	3	5	6	6
Augmenting user experience systems	1	1	1	1	3	3				1	

Figure 3: Digital technology usage over the past 10 years. Each research article may belong to multiple categories, leading to the total number of digital technology labels being greater than 85.

handle more complex graphic designs, such as the parametric design of customized structures and textures [5, 11, 13, 21, 87], unfolding three-dimensional surfaces [31, 80, 88], and optimization of components cutting layouts [45]. Additionally, some other works developed algorithms to simulate the fabricating process and the user experience with the final craft product, thereby enhancing the efficiency of the design iterations. Examples include simulations of fabric folding processes [18], color-changing effects of thermochromic embroidery [19], color-changing effects of polarized light mosaics [73], etc.

Based on the above CAD technologies, 23.5% of the articles also provided customized GUI design tools for different tasks. Some of these design tools helped users to access the graphic design and simulation algorithms in a more intuitive and interactive manner [13, 21, 73]. Others are oriented towards assisting in certain specific tasks, such as sewing tutorials [45] and amblyopia embroidery training [8].

Furthermore, 10.6% of the articles employed computer vision techniques to transform real-world images as material in the pattern design process of traditional crafts. This approach expanded the design space of the crafts and the connection between digital and physical objects [4, 28, 46].

4.2.3 Interactive materials and hardware. Except for the aforementioned use of digital technologies in the design and fabrication process, another significant trend we found in this research is the embedding of interactivity into crafts, transforming static craft product into dynamic user interfaces. This category encompasses the largest number of articles, accounting for 57.7%.

Within this category, 55.3% of the articles focused on adding physical interaction capabilities to the crafts using materials with technical properties, e.g., conductive materials, color-changing materials, and Shape Memory Alloys (SMA). For instance, numerous researchers have introduced conductive threads, inks, and tapes to enable touch or primary gesture recognition in crafts such as embroidery [28, 86], lacquerware [33], textiles [39, 95], ceramicware [93], stained glass [22], etc. Other researchers have combined conductive materials with programmable materials such as thermochromic materials [19, 42, 78], photochromic materials [43], SMA [41, 96], and ferrofluids [59], to embed interactivity of the physical properties to the crafts, with features such as dynamic color, shape, and temperature.

Moreover, this category also includes 47.1% of the articles that directly embedded existing electronic components into crafts to create input and output channels for the crafts. For example, Zheng installed IMU sensors and LED lights in ceramic pots to create a motion-responsive pottery light [94], and Saito embedded RFID chips in lacquerware to produce digitally readable information of the lacquerware. Many researchers also integrated interactive hardware kits (e.g. Arduino Kit) into crafts, such as Chilean Arpilleras [27], Chinese Hairy Monkeys [50], textile story books [64], etc., to enrich the dynamic expressiveness of the crafts with features such as switches, illumination, sound, vibration, motion, etc.

4.2.4 Augmenting user experience systems. Lastly, 12.9% of the articles focused on the augmentation of the user experience in the traditional making process of the crafts through the development of multimodal interactive systems or techniques. For example, Pschetz [68] and Nitsche [59] transformed the knitting action into animation and sound to encourage users to feel the subtle movements of the hand-made knitting process. Sullivan et al. translated the weaving behavior into a game that records the player narrative with fabric's texture [77]. Liu et al. employed AR projection to assist users in learning paper cutting [51]. Posch et al. provided customized conductive pens and needles to support users in the manual fabrication of electronic fabrics [63, 65]. These interactive approaches all contributed to augmenting the user's crafting experience in different directions.

4.3 Target User Group

People are the carriers of traditional craft and are critical to its inheritance and innovation. In this subsection, we categorized the target user to identify the core beneficiaries and service targets of the innovative outcomes of traditional crafts. Figure 4 shows the changes in target user groups over the past ten years.

4.3.1 Experienced Craftsmen & Novice Craftsmen. Craftsmen are the most directly relevant target user group, with novice craftsmen accounting for 13.11%, and experienced craftsmen at 18.03%. Articles for novice crafters in this category focus mainly on developing crafting tools and lowering the threshold of craftsmanship to stimulate interest in learning and help them acquire crafting skills quickly [51, 80]. Leake et al. transferred the 'specialized training' approach from sport and music to sewing, using interactive

Legend: 1 | 2~3 | 4~6 | ≥7

Craft Category	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Novice Craftsmen		1	1	2	1	1	1	1	4	1	3
Experienced Craftsmen			2	1	3	3	3	2	2	1	5
No Specific Users	2		4	1	2	3	1	3	1	2	1
HCI Researcher		1	2	4	5	7	6	4	3	6	4
Teachers & Students		1		1		1	1		1	3	
Vulnerable Groups			1			2	3	1	3	2	2

Figure 4: Changes in target user groups over the past 10 years. Note that each article may target multiple user groups, causing the total number of identified user group labels to be greater than 85.

techniques to assist in the customization and design of sewing tasks [45].

Articles for experienced craftspeople focus on expanding the expressiveness of traditional crafts and providing new knowledge based on existing craft processes [9, 14, 33, 71, 74], while developing more professional tools to support craftspeople in their creative endeavors [19, 51, 65]. For example, Zoran's series of works innovate the expressiveness of woodworking through parametric design [55]. Nakamura et al. expanded the interactivity of traditional lacquer art through conductive materials while providing new design space for lacquer artisans [33, 71].

In addition to this, Carrascal et al. combined NFT with the craft production process to expand the dissemination of craft culture in a commercial format, as well as the crafts market for craftspeople [9]. Some works also explored the opportunities for cross-collaboration between the HCI committee and the craft domain, which can reflect on their respective tools and practices from different cultural contexts, thus providing new avenues for interaction or craft design and examining the subtle relationship between craft culture and technology [35].

4.3.2 No Specific Users. 16.39% of the articles refer to no specific users as the target user group. This definition is not aimed at any particular user, craftsman, HCI researcher, or special group. Instead, it highlights the concept of crafting in a democratic and universal way [58], meaning that it is accessible to everyone with low learning costs, simpler processes and is not limited by expertise or background [75, 77, 88, 96]. The focus of these papers is on common and ordinary scenarios in which users can use craft as sound speakers, clothing, bags, and other daily necessities, emphasizing the accessibility of hybrid crafting processes and hybrid handicrafts [47, 48, 75], rather than focusing on exquisite home decoration or interface design with higher technological content.

The value of craft lies in the slow process and the sense of participation it provides. Articles such as Pschetzet al. and Itzhaket al. emphasize the use of technology to enable makers to enjoy handwork as a pastime rather than focusing solely on the difficult production process [24, 68].

The craft methods or material inspirations described in these papers are often derived from everyday life experiences, and their contributions also feed back into daily life, used to enhance or inspire the experiences of daily living [47]. For example, Nabil et al. provided a design case on soft textile speakers to provide all users with simple, easy-to-use materials and low-barrier technologies, embracing individualized needs [58].

Besides, since these articles are not specifically aimed at any particular user, the barrier to entrance for layperson readers is lower, allowing more readers to find resonance or consensus in the papers [24, 68]. For example, some papers identify 'powerlessness' as a common theme in developing traditional craft [86].

4.3.3 HCI Researchers. Not all papers explicitly mention whether they target HCI researchers or their equivalent. Instead, we rigorously analyze the type and complexity of their contributions in terms of techniques, materials, and knowledge and consider those that require specialized backgrounds in HCI engineering, design, or interdisciplinary areas. We found that 34.43% of articles targeted HCI researchers as users.

Articles with HCI researchers as a target user focus on fabrication technologies [61, 70], materials science [1, 40, 56], interactive interface technologies [62, 95], and technology or design toolkits [50, 54, 60, 83] related to traditional craft, which is based on advanced technology. In addition to engineering-oriented contributions, these papers also emphasize extracting "tacit knowledge" in the process of craft production and transforming it into theoretical methods, design spaces, or opportunities for HCI committees, such as craft-related technical, literary, historical, artistic knowledge, or the intrinsic experiences of artisans [20, 23, 54, 56, 69]. For example, Moradi et al. took glaze technology as a perspective to analyze the practical process between humans and craft materials, further discussed it as tacit knowledge to examine the turning point for materials transforming from physical attributes to digital attributes and then to the lifelong materials [56]. Lu et al.organized a workshop on Cantonese porcelain and digital technology, revealing that people need to accumulate more tacit knowledge about intangible cultural heritage techniques, skills, materials, colors, and patterns beforehand in order to better evaluate intangible cultural heritage design[23].

Besides, these articles encourage HCI researchers to collaborate with researchers from other disciplines to extend current research methods in HCI, such as working with historians and cultural critics by studying craft products from historical sites [69]. This category also highlights an understanding of the core carriers of innovation - people [15, 53, 92, 94], focusing on using HCI methods to support people involved in crafts or to improve their interaction experiences, as well as the people behind craft and craft ecosystems.

4.3.4 Teachers & Students. 6.56% articles explicitly highlight the role of teachers and students as participants. It is different from the articles aimed at novice craftsmen. This type focuses on the integration of traditional craft and digital technology into STEAM education, with particular interest in curriculum, teaching tools, teaching processes, and reflection on design practice [18, 27, 36, 43]. They emphasize the possibility of combining traditional crafts with the curriculum by facilitating interactive materials. Interestingly, as not all students are handicraft enthusiasts, their design ideas are not bound to the core artistic characteristics of current handicrafts; they are diverse and imaginative [27, 59]. It can further promote cultural heritage's dissemination, innovation, and vitality and enable craftspeople to acquire new knowledge and skills [38, 54].

4.3.5 Disabled People, Aging people, Children, and Women. In recent years, the field of HCI has begun to benefit vulnerable groups through hybrid crafts, accounting for 11.48% of the total. In terms of caring for people with disabilities, these efforts use traditional craft as a medium to explore how craft techniques and art can have a positive impact on their self-awareness or expression and to create meaningful craft products [24, 26, 57]. They can also assist disabled people in rehabilitation training [8], and some works have been carried out to extend the boundaries of interactive technology by involving disabled people as participants or co-creators.

Motivated by the aging population, several articles sought to understand senior maker activities and methods to involve older adults in digital crafting [36, 37]. These papers pay attention to the design of age-friendly toolkits and refocus public attention on the precious story by recounting a craft technology workshop once participated by a group of older adults, thus indirectly rekindling public attention on the elderly population [69].

Of these articles, only one relates to children. This article takes a craftsman's perspective on how interactive, tactile, and multi-sensory technology can be integrated into textile book storytelling and enhance the quality of the reading experience for young readers [64].

Only a few papers deal with the women group, but we can identify some common viewpoints in these papers. They do not only focus on the aspects in which women excel in traditional crafts but also aim to break gender stereotypes. For example, women are not only skilled in weaving or handicrafts [69] but also have a sensitivity to the diversity and novelty of technology and materials [95]. These papers advocated design empathy and equal pay and encouraged mutual respect and humility in craft design [15, 27, 69].

We have noticed these papers focused on specific user groups and are pleased to see that they are exploring traditional craft to accommodate different user behaviors. Currently, these papers still need to be more numerous, and there are more specific user groups that deserve attention.

5 ANALYSIS RESULTS FROM RESEARCH AREA PERSPECTIVE

5.1 Overview of Research Areas

Based on the above craft categories, digital technology usage, target users, and the articles' motivation and contribution, we initially categorized the 85 articles into five research areas and 13 sub-research areas, providing directional references for innovating and enlivening traditional crafts.

Figure 5 illustrates the development trends among various research domains from 2013 to 2023. "New Craft, Material, and Interactivity" and "Enhancing Crafting Experience" developed earlier and maintained a steady yearly research output. Starting in 2017, researchers began to focus on "People, Community, and Ecology," while from 2021 onwards, educational research topics had a noticeable growth. On the other hand, "Perspectives, Theories, and Reflections" appeared in limited numbers in most years.

Figure 6 depicts the distribution regions of the five research areas. We observed a significant degree of overlap in the data distribution for the five areas. Specifically, "Enhancing Crafting Experience" and "New Craft, Material, and Interactivity" exhibit the widest distribution, nearly encompassing the entire distribution plot. "Education and Therapy" and "People, Community, and Ecology" cluster towards the left side of the distribution. "Perspectives, Theories, and Reflections" have a greater horizontal spread but a smaller vertical spread. Further analysis of this distribution based on the content of the selected 85 articles reveals that:

a) "Enhancing Crafting Experience" covers almost every crafting aspect, resulting in an extensive distribution. At the same time, the arrows within this research area are associated with digital fabrication-related design tools and hardware technologies. Therefore, the application scenario of these technologies is closely related to enhancing the crafting experience.

b) The coverage area of "New Craft, Material, and Interactivity" is similar to that of "Enhancing Crafting Experience," but there are also some differences. "New Craft, Material, and Interactivity" is more concentrated above the axes, with a slightly greater impact from interactive elements. In terms of target users, the primary beneficiaries of this research category are HCI researchers.

c) "People, Community, and Ecology" is situated in the bottom-left corner of the chart, distant from interactive and technological factors. Textiles are widely employed in this domain due to their inclusivity and availability.

d) Compared to "People, Community, and Ecology," "Education and Therapy" places a greater emphasis on interactive elements.

e) "Perspectives, Theories, and Reflections" is an open-ended theme aimed at reflecting through design practice. Hence, it overlaps with all research areas.

Taking into account the above findings from Figure 5 and 6, we observed that these research areas exhibit a structure transitioning from layer-by-layer emergence to high overlap, progressing from artifact innovation to a focus on human aspects, and then culminating in theoretical reflections. The two most prominent research areas emphasize artifact innovation, covering the current

Legend: 1, 2, 3, ≥4

Five Research Areas	Sub-research Areas	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
New craft, Material, and Interactivity	Enhancing traditional craftsmanship			2	1		1		1	1		3
	Interactive materials and interface		1	1	2	3	4	1	2	2	3	3
	Evocative Artwork			2	1		2	1		1		1
Enhancing Crafting Experience	Crafting process aids	1			2	3	5	3	3	4	3	3
	Promote crafting enjoyment	1		1	1	1	2		1			
People, Community, and Ecology	Collaborative creation of multiple roles					2			1			
	Craft community and ecology							2	1	1		
	Understanding crafting process						1	1		1	2	1
Education and Therapy	Education tools									1	2	2
	Teaching practice		1				1			1	1	
	Therapy										1	
Perspectives, Theories, and Reflections	Concept analysis						1	1				
	Design reflection			1	1	1	1	1	1		1	

Figure 5: Count of research areas for the 85 selected articles sorted by year of publication. Note that each article may be related to multiple sub-research areas, causing the total number of sub-research area labels to be greater than 85.

research domain of hybrid craft cases related to traditional craft. Building upon artifact innovation, researchers have started to understand the human, community, and ecological aspects underlying hybrid crafts and have identified specific applications of artifact innovation, particularly in education. Ultimately, these findings lead to reflections informed by various practices, contributing to constructing theories and perspectives.

We will introduce these research areas in the following subsection. Understanding these research areas may obtain inspiration for the direction of innovating and enlivening traditional craft.

5.2 New Craft, Material, and Interactivity

According to the innovative result, we summarized three types of innovative artifacts as references for related practitioners that use hybrid craft methods to innovate and enliven traditional crafts.

5.2.1 Interactive materials and interface. Traditional crafts provide various materials, crafting techniques, and forms for HCI, offering new inspirations and physical media for digital technology innovation. This research area mainly focuses on leveraging traditional crafts' affordance and integrating digital technology to transform traditional crafts into interactive materials and interfaces, which is the largest sub-research area, accounting for 20.95% of the articles. For instance, the aesthetic, flexible, and skilfully manipulated media of the weaving craft inspired Ku et al. to combine Shape Memory Alloy (SMA) with weaving techniques, leading to the development of a set of detachable and reconfigurable deformation interfaces called "Patch-O." Patch-O can be sewn or attached to different positions on clothing or skin, enabling bending, expansion, and contraction, thus enhancing people's social expressions [41]. Endow et al. integrated thermochromic liquid crystals and conductive wires into embroidery, transforming embroidery from a traditional craft into a liquid crystal textile display. Similar cases include fabrics capable of recognizing gestures [19], flexible fabric speakers [58], and interactive ceramics [93], etc.

5.2.2 Enhancing traditional craftsmanship. 8.57% of the articles focus on using digital technology to enhance traditional crafts' expressiveness and design possibilities, including breakthroughs in form and the transition from static to dynamic creations. For instance, EscapeLoom offers a 3D printed framework with customizable warp density and form to enrich static forms. Users can freely weave with fiber materials on the 3D framework, extending creation from a 2D space to a 3D one and breaking away from traditional weaving techniques [13]. Similarly, Valle et al. offer rich and robust aesthetic frameworks for punch needle crafting, applied in producing clothing, accessories, and decorations [11]. Regarding dynamic craft production, researchers use digital technology to add a temporal dimension to traditionally static crafts, introducing narrative elements. For example, Liu et al. incorporated interactive mechanisms to create dynamic works such as the "Hairy Monkey Symphony Orchestra" and the "Hairy Monkey Buddha Device" [50].

5.2.3 Evocative artwork. The physical media underlying traditional crafts bring about rich sensory experiences and provide creators with diverse material carriers. Turning traditional crafts into evocative artwork, such that viewers can resonate emotionally and be intellectually inspired, is also a way to enliven traditional crafts. It is featured in 7.62% of the articles, where examples include Wang et al.'s interactive embroidery [86] and CRAFTED LOGIC [66]. Specifically, Wang et al. noticed the "sense of powerlessness" in the traditional embroidery industry and embedded the environmental

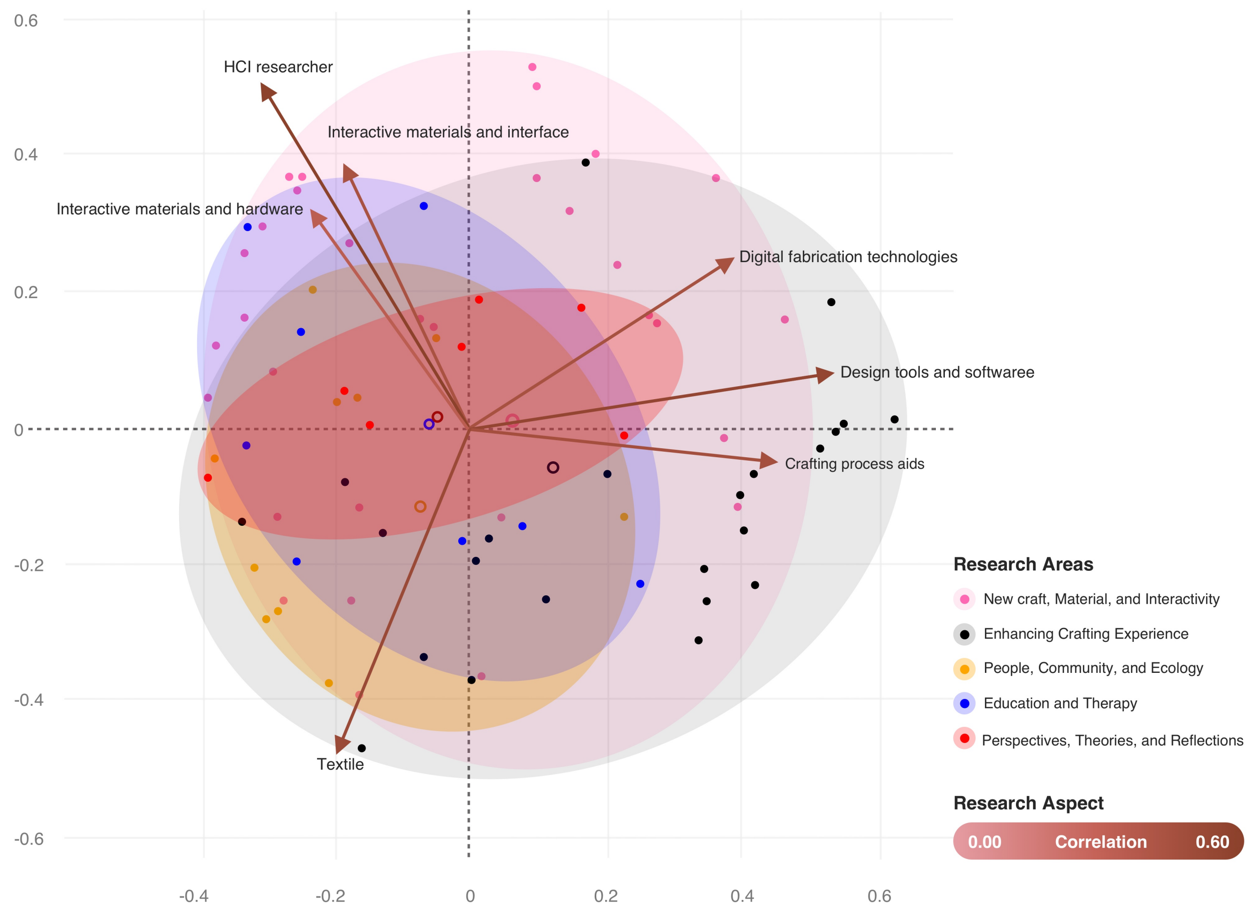

Figure 6: Distribution regions of the five research areas: small dots represent the individual articles, hollow circles represent the centers of each trend region, and the arrows represent the distribution of the most significant seven research aspects. The position of each dot (corresponding to each article) is determined by performing PCA on the feature matrix, in which the multi-dimensional label representations of each article are reduced to two dimensions, namely, X and Y. Hence, the 2-D visualization can be plotted to illustrate the (dis)similarity of articles. Each trend region that contains articles of the same category is inferred and manually drawn by the authors based on the rule of covering those same-typed articles within the minimum area. This analysis method is the same with paper [91].

sounds of the artisans' working process into the embroidered works. These sounds are played when users touch the embroidery, trying to stimulate people's existing imagination of cultural consciousness. CRAFTED LOGIC is an interactive installation consisting of fundamental logic gates created by various textile-crafting techniques. The artwork's intention was to provoke imagination about alternatives to existing computing technologies.

5.3 Enhancing Crafting Experience

This research area inspires practitioners to focus not only on the innovative outcomes of traditional crafts but also on the crafting process itself. Researchers can develop assistive tools to help users create their desired works. Additionally, they can enhance the enjoyment of the crafting process through methods such as musicalization, visualization, gamification, and other engaging approaches.

5.3.1 Crafting process aids. 25.71% of the articles focus on crafting process aids. Through techniques such as visual programming, creative guidance, and assisted fabricating, these tools lower the barriers to creation, allowing more people to participate in the innovation of traditional crafts. For example, Honeycomb smocking is an ancient handicraft that provides elasticity to non-elastic fabrics used in clothing. Crafting Honeycomb smocking is difficult and time-consuming, and creating complex, innovative patterns can be even more challenging due to the need for complicated mental calculations and pattern planning. Researchers drew inspiration from the repetitive and structured patterns in this craft and developed a system called "Hybrid Bricolage" to assist users in the crafting process. The creators need to complete the design of the Honeycomb smocking pattern in the design software, which will then generate a guidance file. They then use this guidance file to carry out the sewing and crafting process. The results of a creative workshop involving eight fashion designers showed that this system effectively reduces the cognitive burden on the creators and assists them in producing innovative works [18].

In addition, some articles explore the method of human-computer collaborative creation, which provides real-time inspiration for creators and allows them to intervene creatively during the creative process. For instance, Leake et al. developed a design tool called PatchProv for improvisational quilting practice. In this process, users can capture physical pieces of fabric, experiment with them digitally in PatchProv to receive design suggestions, and then continue to iterate with the physical fabric. In a similar vein, Albaugh et al. digitally transformed a Jacquard loom. This digital loom uses a camera to recognize patterns, enabling the weaver to intervene creatively in the weaving process while the fabric is being woven [46].

5.3.2 Promoting Crafting Enjoyment. 6.67% of articles focused on promoting crafting enjoyment, using gamification and other techniques to enhance the enjoyment of the crafting process, and guiding creators to pay attention to their feelings during the crafting process rather than solely focusing on the final craft product. For instance, Albaugh et al. [2], and Sullivan et al. [77] combined the sewing process with a game operation, making the crafting process a game. The result of playing the game became a new textile work. Schoemann et al. present a human-computer collaboration hybrid embroidery game with a hardware setup, including an embroidery machine, laptop, and a swatch scanner [47]. Players can draw patterns on the target fabric when playing and then scan the pattern's path using a scanner. Subsequently, the machine will creatively create embroidery patterns based on the user's drawing. Afterward, players can continue to draw creative patterns based on the embroidery results and hand them over to the hardware setup for further collaborative embroidery. In addition, it is possible to musicalize [72] or visualize [68] the movements during crafting, resulting in a novel creative experience.

5.4 People, Community, and Ecology

This research area focuses on people as the makers and consumers behind traditional crafts. To bring about innovation, practitioners need interdisciplinary collaboration with professional craftspersons, engineers, designers, etc. Through observation, interviews, and hands-on making, practitioners can understand the crafting process, identify user pain points, and address specific creative challenges. Practitioners should also pay attention to the communities and ecosystems behind the craft, ensuring the sustainable circulation of craft products in the market.

5.4.1 Collaborative creation of multiple roles. Hybrid crafts usually require the collaboration of people from various disciplines. Therefore, how to efficiently lead this diverse group of people to work together has become increasingly important. For example, Zheng et al. [94] explored the collaboration process between designers and ceramicists, suggesting that giving both roles sufficient creative space and equal participation can promote collaboration. Devendorf et al. documented a six-week artist residency program that focused on how to incorporate the vision of traditional craftsmanship into the early stages of the creation of new interfaces, so that artisans and designers could work together in a mutually beneficial way, while prioritizing the original "techniques" of traditional craftsmanship that could lead to further breakthroughs in interface innovation. [15] Tsaknaki et al. [82] described a year-long collaboration between a designer and a silversmith, during which the designer drew on the unique qualities of silver craftsmanship to provide new information for interaction design, as well as discovering the challenges of combining the two fields at the level of materials, tools, and techniques.

5.4.2 Understanding crafting process. Understanding users is an essential part of conducting design work. This sub-research area aims to understand individuals' pain points and needs in the crafting process and propose design suggestions and tools to assist them. Most of the articles focus on vulnerable groups. For example, Giles et al. [24] demonstrated how visually impaired individuals create meaningful items through electronic textiles. Jelen et al. [37] explored the electronic textile experiences of older adults, to design electronic textile toolkits and instructional courses for them. Muehlbradt et al. [57] explored how wearable textile interfaces for recording physiological data could be meaningfully integrated into the lives of people with disabilities, such as through the use of sensors and displays that can be incorporated into the design of wearable textile interfaces that are more suitable for them. Besides vulnerable groups, Moradi et al. [56] observed the glazing process of professional ceramicists to understand how craftsmen and materials interact and form a collaborative relationship. This relationship provides a perspective for the creative process of hybrid craft and helps people understand the relationship between digital materials and makers in hybrid crafting.

5.4.3 Craft community and ecosystem. A few articles (4.3%) focus on the ecology behind the crafts, including the community of people who create traditional crafts and the socio-economic structure that influences the circulation of craftwork into the market. Twigg-Smith et al. [83] investigate PlotterTwitter, an online community where hybrid craft enthusiasts gather. The researchers find that such online communities are pioneering increasingly novel fabrication workflows, are crucial to moving beyond traditional fabrication models, and can provide design guidance for future hybrid craft authoring toolkits. Both Zhang et al. [92] and Lu et al. [53] investigate how particular crafts are produced and disseminated, starting with local traditional crafts and explore how digital technologies can help the circulation of crafts in the market. Zhang et al. also emphasize the importance of focusing on the social infrastructure behind the crafts.

5.5 Education and Therapy

This research area focuses on integrating traditional crafts into STEAM education. Students can benefit from learning both digital technology and traditional culture while experiencing the joy of handmade crafts.

5.5.1 Education tools. 4.76% of the articles focus on "education tools" as their research subject, emphasizing the development of teaching tools to impart crafting skills to students. One research category draws inspiration from traditional crafts and applies them to digital craft education. For instance, Jones et al. [38] discovered that in E-textile education, students encounter two types of challenges: 1) acquiring tacit skills of stitching with a needle and thread, and 2) becoming proficient in basic electronic engineering - such as how to create a functioning circuit. Inspired by stitch samplers of traditional embroidery, which are tangible references for learning, practicing, and demonstrating stitching techniques, researchers developed an e-textile stitch sampler to help individuals practice the tacit skill of stitching while learning how to make e-textile patterns.

Other studies aim to teach students specific traditional crafts through educational tools, including software and hardware, instructional manuals, etc. For example, Leake et al. [45] found that learning sewing tasks through online videos yielded bad results and incurred high trial-and-error costs. To address this, researchers drew inspiration from deliberate practice methods used in sports and music fields and developed the instructional software "InStiches." They aimed to achieve teaching goals that respect traditional crafts, offer personalization, and promote environmental sustainability through digital technology. Similarly, Devendorf et al. [16] provided a weaving technique instructional manual as a pictorial to assist HCI researchers.

5.5.2 Teaching practice. 3.81% of the articles incorporate traditional craftsmanship into teaching practices, focusing on curriculum design and emphasizing reflection through teaching practice. For instance, Nitsche et al. offered a digital craftsmanship course at the Georgia Institute of Technology, where students were required to create Turkish traditional Ebru paintings and weaving crafts digitally. The emphasis of the teaching was not just to help students become proficient in specific traditional crafts but to encourage them to generate deeper thoughts through understanding materials and craft processes [59]. Guridi et al. combined a Chilean textile art called Arpilleras with electronic textile technology and engaged designers and artisans to conduct teaching practices in local schools. Through this practical approach, the authors reflected on how traditional craftsmanship and digital technology can mutually benefit in an educational context [27]. Lu et al. explored how students could learn Intangible Cultural Heritage (ICH) knowledge through the "Crafts + Fabrication" workshop. They also reflected on cultural authenticity and tacit knowledge based on students' creative practices [54].

5.5.3 Therapy. One article takes an innovative approach by utilizing traditional craftsmanship to treat amblyopia patients, opening up a new scenario for revitalizing traditional crafts. Cao et al. [8] developed an embroidery-based therapy system for people with amblyopia. During the treatment, patients must complete embroidered patterns generated by the system daily. This practice aims to improve their visual conditions through hand-eye coordination training.

5.6 Perspectives, Theories, and Reflections

Lastly, "Perspectives, theories, and reflections" call upon researchers to engage in reflective design practices and propose viewpoints and theories. The interaction between theory and practice can mutually enhance each other. By following the path of practice-theory-practice, we can drive the innovation of traditional crafts and the development of hybrid craft fields.

5.6.1 Design reflection. The relationship between craftsmanship and digital technology, as well as the interplay between the uncertainty of craftsmanship and the determinism of digital technology, is the research focus of 6.67% of the articles. For example, Cheatle et al. researched and interviewed craftsmen associated with the American furniture manufacturer Wendell Castle. Through this study, they reflected on the issues of creativity and collaboration at the intersection of woodworking craftsmanship, digital technology, and material practices [10]. Saegusa et al. reflected on the role of digital manufacturing systems as copiers, translators, and connectors in craftsmanship through clay production practices using the digital carving tool "Arc machine" [70]. Rosner et al. called for a collective interpretation of an artwork as a culture probe, aiming to reflect on the contributions of women behind technological advancements [69]. Albaugh et al. studied how craftsmanship uncertainty and digital technology determinism affect artificial artifact production in the digital craft. They modified a Jacquard loom into a digital tool, allowing weavers to creatively intervene during real-time weaving using three modes, including cut-paper mode, self-portrait mode, and live-streaming mode [4].

5.6.2 Conceptual analysis. The emergence of numerous hybrid craft practices has prompted some researchers to focus on conceptual analysis, accounting for 1.9% of articles. For instance, Frankjare et al. [20] studied craft-based inquiry in HCI, clarifying the definitions of hybrid craft, digital craft, computational craft, and technocraft. They also identified characteristics of craft-based inquiry in HCI, which include 1) combining analog and digital crafting techniques and processes, 2) creating refined objects with attention to detail and aesthetics, and 3) generating knowledge through deep, embodied engagement.

6 REFLECTIONS: A DESIGN FRAMEWORK FOR INNOVATING AND ENLIVENING TRADITIONAL CRAFT

In the previous sections, we reviewed 85 articles from the perspectives of craft category and innovative results, digital technology for craft innovation, target user group, and research areas. It provides concrete and direct reference cases for innovating and enlivening traditional crafts. Based on reflections from these cases, we propose a design framework shown in Figure 7, consisting of three layers: value judgment, artifact innovation, and people involvement.

Regarding value judgment, traditional craft and digital technology sit at opposing ends of the scale. The scale indicates if innovation leans towards enhancement or transformation (subsection 6.1). The choice of innovation paradigm is a value judgment, guiding how traditional crafts should be innovated and revitalized to be more valuable. For artifact innovation, we witness two innovative outcomes for traditional crafts: craftwork and creative tools, mutually reinforcing each other (subsection 6.2). We place "People participation" at the top of the design framework, underscoring its significance. Artifact innovation must serve people for sustainable contemporary inheritance and innovation (subsection 6.3).

In applying this framework, practitioners first need to judge how traditional craftsmanship should be innovated and revitalized for more excellent value and choose specific innovation paradigms.

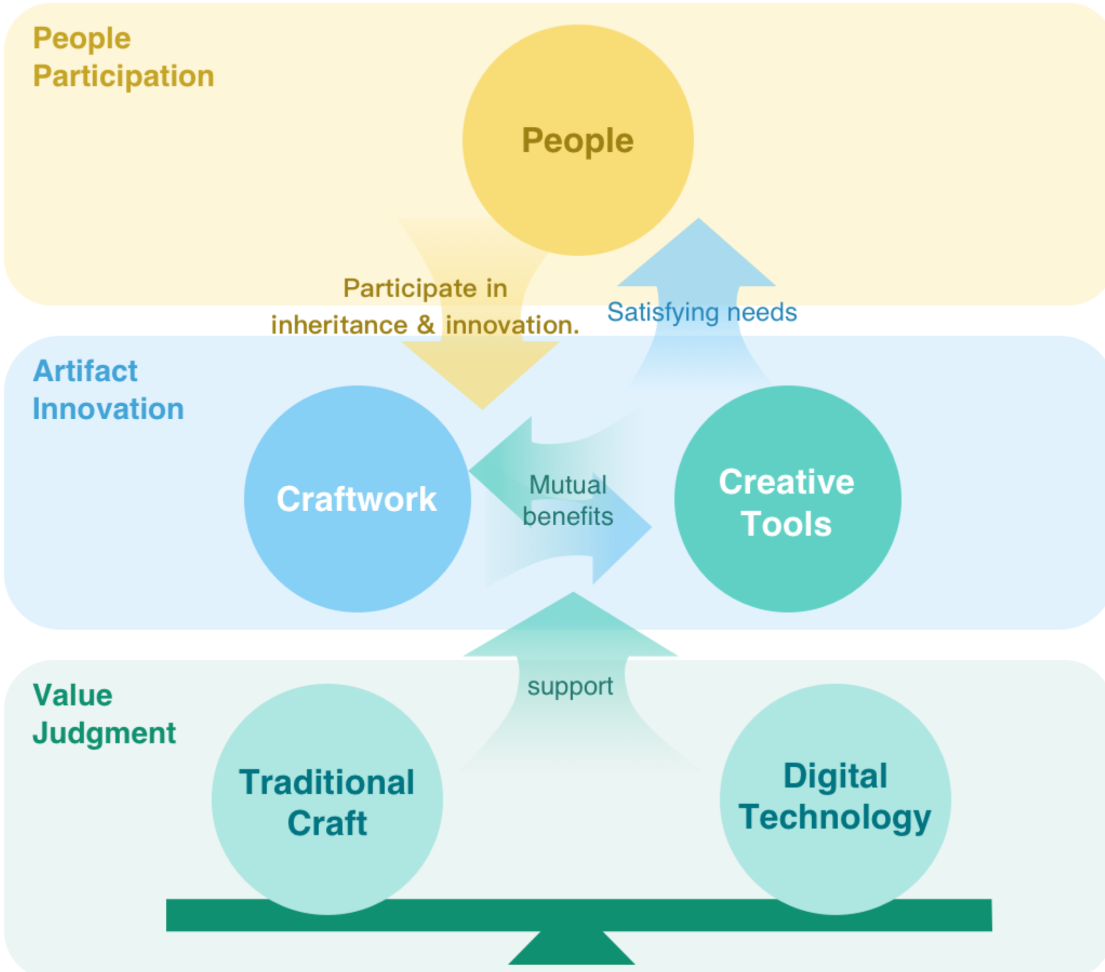

Figure 7: Design framework for innovating and enlivening traditional craft.

Subsequently, innovation is carried out at the level of craftwork and creative tools to meet people's needs, attracting public attention and promoting democratic participation, leading to the sustainable inheritance and innovation of traditional craftsmanship.

6.1 Value Judgment: Enhancement-oriented Innovation or Transformation-oriented Innovation

Since the Arts and Crafts Movement, the relationship between handicrafts and technology has been constantly discussed. In the current digital age, this relationship remains the starting point for a lot of research and important reflection in hybrid craft research [10, 70]. Handicrafts and digital technology have inherent contradictions. As explained by the crafts theorist David Pye, handicraft is a "Workmanship of Risk," relying on the maker's accumulated practical experience to possess stability of judgment and dexterity. On the other hand, crafts produced predominantly through digital technology are characterized by mass production, automation, and standardization, embodying a kind of "workmanship of Certainty." [52] The application of digital technology to traditional crafts becomes a matter of degree [50]. Researchers have started to question the practicality of using digital fabrication machines, as they argue that it may remove the joy and beauty from manual work and limit creative exploration through traditional handcraft [13]. This has sparked discussions about cultural authenticity [6, 54], cultural genes [49], computational shadows [31], and other related topics.

Through literature review, we have proposed two paradigms for traditional craft innovation and enlivenment based on the relative dominance of digital technology and traditional craftsmanship: "enhancement-oriented innovation" and "transformation-oriented innovation."

Specifically, we define the innovation paradigm where digital technology assists traditional craftsmanship as "enhancement-oriented innovation." This type of innovation emphasizes preserving the core attributes of traditional craftsmanship, such as materials, artisanal techniques, and aesthetic characteristics. The essential crafting processes retain the "thinking through hands-on practice. The incorporation of digital technology expands the creative space of the craft and assists creators in reducing repetitive physical labor and complex mental calculations, thereby lowering the entry barriers to crafting and enabling a simpler and more efficient creative process. This pathway is rooted in cultural authenticity and the essence of craftsmanship. Much of the work in research areas 5.2.2 falls into this category. Relevant examples include EscapeLoom [13], Bamboo Agent [23], Hybrid Bricolage [18], etc.

The innovation paradigm where digital technology takes the lead and traditional craftsmanship assumes a secondary position is known as "transformation-oriented innovation." In this approach, digital technology intervenes to replace the core materials or techniques of traditional craftsmanship, altering the predominant characteristic of manual production. The core crafting process is carried out by computer-assisted fabrication equipment, with manual work playing a role in assembly, repairs, and other auxiliary tasks. Relevant examples include 3D-printed ceramics and the creation of interactive textiles using digital embroidery machines [14, 28]. We have also observed that traditional crafts have provided inspiration and material support for designing new materials and interfaces. For instance, interactive interfaces and sensors based on glass and lacquer art have emerged as a result [22, 33]. By transforming traditional craftsmanship into interactive interfaces, traditional craftsmanship has gained new functions and renewed vitality.

We believe that both of the aforementioned innovation paradigms hold their own value. "Enhancement-oriented innovation" emphasizes cultural inheritance and enables traditional craftsmanship to retain its essence while evolving with the times. In "transformation-oriented innovation," the authenticity of the transformed traditional craftsmanship may diminish and, to some extent, not be perceived as the original traditional craftsmanship itself. However, it gains derivative values such as new functionalities, potential for mass production, enhanced user experiences for newcomers, and broader dissemination.

The assessment of the value of the two innovation paradigms – enhancement-oriented and transformation-oriented – in future creative endeavors depends on the specific nature of the craft. Factors like reputation, inheritance, technical complexity, and material availability play a role. For crafts with complex techniques and strong inheritance, enhancement-oriented innovation can be pursued while retaining core elements. For crafts with limited recognition, transformation-oriented innovation involving digital technology could be explored to lower barriers and broaden participation. Future researchers can develop methods and theories by continuously aligning innovation paradigms with craft attributes to guide practical applications.

6.2 Artifact Innovation: Mutual Benefits between Craftwork and Creative Tools

As described in Section 5, hybrid craft has brought about two innovation outcomes. One type is the innovation in craftwork, where researchers utilize various digital technologies to expand the expressiveness of traditional craftsmanship, leading to rich display effects. As shown in Section 5.2, these effects include deformation [3], color changing [19], spatial transformations [50], increased interactivity [93], and enriched sculptural forms [55]. The other type of outcome is the innovation in the crafting process, primarily achieved through the development of design tools and software and the use of digital fabrication technology. These tools play a role in stimulating creative inspiration [46], reducing the barriers to craft production [80], and promoting crafting enjoyment [72].

Through reflection on the literature, we have identified the potential for mutual benefit between craftwork and creation tools, resulting in two innovation paths. Specifically, researchers can gain a deep understanding of the pain points and needs within the process of innovating craftwork by collaborating closely with artisans, engineers, and other relevant collaborators. Researchers can further design and develop creative tools to democratize individual creative processes, thereby attracting more participants to engage in innovation on traditional crafts. It essentially forms an innovation path of craftwork to creative tools.

In the innovation path from creative tools to craftwork, the emergence of creative tools can attract numerous target users to participate in the innovation of traditional crafts. With the assistance of creative tools, participants can create a series of prototype-level demo works. Although these works may not be complete or technically perfect, they encapsulate the creative ideas of the participants. Through interviews with participants to understand their sources of inspiration in the creative process, practitioners can obtain inspiration and collaborate further with professional artisans to complete comprehensive innovative craftwork.

Therefore, in the future, when using digital technology to empower innovation and enliven traditional craftsmanship, practitioners can simultaneously explore breakthroughs in both the innovation of craftwork and the creative assistance in the crafting process. Walter Benjamin once proposed in his article "The Work of Art in the Age of Mechanical Reproduction" that work's aura disappears through mechanical reproduction [7]. The rise of digital technology may impact traditional craftsmanship and lack the human touch. However, we believe that hybrid craft, to some extent, not only preserves the uniqueness and creativity of manual creation but also integrates the computational advantages of digital technology. Therefore, in innovating and revitalizing traditional crafts, we should actively embrace digital technology and apply it ingeniously to achieve the contemporary transformation of traditional crafts, embracing the "future craftsmanship" of the digital era.

6.3 People Participation: From Professional Craftsmen to Democratized Inheritance and Innovation

Sustainable innovation and the development of traditional crafts are inseparable from the participation of people. Traditional crafts require "living transmission," and this kind of inheritance should not be limited only to the inheritors. It is essential to allow innovative traditional crafts to circulate in the general public's lives and be relevant to modern living [76]. Through the previous literature review, we see that hybrid crafts have promoted the democratization of innovation. As described in section 4.3, from craft practitioners to HCI researchers, teachers, and students, and even to people with disabilities, older adults, and children, all have become participants and beneficiaries of hybrid craft.

On the one hand, in traditional society, learning traditional crafts relied on the apprenticeship system, where students needed years of training to create crafts. The emergence of computer-assisted creative tools has lowered the threshold for craft production, allowing people interested in crafts but lacking traditional craft-making skills to integrate their own creativity and produce works that align with their preferences [73]. On the other hand, creating a fine craft piece is not the only goal; the crafting process itself holds value and can be beneficial. For example, as sections 5.5, 5.3.2, and 4.3.5 shows, in the STEAM context, the mutual benefits of combining traditional crafts and digital technology allow students to learn both about traditional culture and digital skills [27]. The hands-on crafting process can also promote students' reflection and insights [59]. Using digital technologies for crafting can also facilitate self-awareness and expression for people with disabilities [24], contribute to therapy [8], involve older adults in technological trends [37], and provide creators with joy and relaxation [77].

We have found that the value of people participation is beginning to emerge, ranging from innovation in the crafts themselves to an emphasis on understanding people through making crafts. The main focus of traditional craft inheritance and innovation is shifting from professional craftsmen to the general public, and people's needs are also transitioning from functional requirements of crafts to experiential desires. In future innovations, researchers can adopt a human-centered perspective to focus on the innovation of traditional crafts, meeting the specific needs of different groups of people, and transforming the general public from bystanders of traditional crafts into creators and innovators. It will continually attract the public's participation in the innovative inheritance of traditional crafts.

7 FUTURE WORK AND LIMITATIONS

7.1 Crafting Tomorrow: Exploring Cultural Artifacts at the Intersection of Technology and Tradition

Advanced digital technology and traditional craftsmanship have become two forces influencing and mutually changing each other. HCI, representing modern diverse technologies, has gradually permeated the transformation and innovation of traditional crafts. It bears many similarities to the Arts and Crafts Movement and modernist design movements, especially regarding their core ideas: finding various ways to integrate technology, craftsmanship, and artistic design in a rapidly changing modern environment, representing an exploration and response to uncertainty.

Although hybrid craft, as a blend of technology and craftsmanship, has injected strong innovative capabilities into traditional craftsmanship in the present day, in many HCI research projects, traditional crafts are often deconstructed into "production techniques." This results in overlooking traditional crafts' cultural and historical factors, leading to a lack of design-driven patterns based on cultural factors.

Building on this reflection, we propose the concept of "cultural artifacts" for the future development of hybrid craft. This concept represents a probe into the future of craft. On the one hand, it advocates for future creators to integrate cultural factors into the design and development process of hybrid craft, delving into the philosophical aspects hidden beneath craftsmanship, focusing on the individuals engaged with craftsmanship, and encouraging the creation of interactive designs, experiences, and innovations deeply connected to modern society and enriched with cultural diversity. On the other hand, it promotes historical retrospection in design, drawing lessons from the past. Only through the fusion of traditional and contemporary cultures can a sustainable and intimate connection between the art of craftsmanship and human life be established.

7.2 Limitations

Firstly, we selected 85 papers from influential publications in CHI, DIS, TEI, and others. However, it also led to the need for more niche publications relevant to the subject of this research. Nonetheless, this paper does not aim to cover all the literature in the hybrid craft field comprehensively but rather to reflect on the vitality of traditional craftsmanship by summarizing a representative set of papers. In the future, researchers can draw inspiration from niche publications, integrating broader knowledge to contribute to traditional craftsmanship's preservation, inheritance, and innovation.

Secondly, the design framework proposed in Figure 7 is a preliminary reflection based on the multi-perspective review of 85 papers. In future work, we will use this framework to guide design practice to evaluate its effectiveness.

Lastly, the target of the design framework—traditional crafts—refers to cultural heritage with cultural connotations and inheritable cultural value. Nevertheless, not all 85 articles delve into history and culture, which is a limitation. However, the quantity is too small if only articles related to culture in hybrid craft are selected for review. Beyond cultural connotations, we believe these diverse results of hybrid craft innovation involving digital technology and materials have already inspired the innovation and revitalization of traditional crafts. Simultaneously, as there is insufficient discussion of culture in the 85 articles, we propose the concept of "culture artifact," inspiring future researchers to integrate cultural elements into the study of hybrid craft.

8 CONCLUSION

This article conducts a literature review of hybrid craft cases related to traditional crafts, investigating and reflecting on traditional crafts' innovation and enlivenment issues and providing insights into the living transmission of traditional crafts through hybrid craft. To carry out this study, we selected and analyzed 85 influential hybrid craft publications related to traditional craft from the past decade. We first conducted reviews from the perspectives of craft categories, digital technology, and target users. Subsequently, based on these articles' research questions and contributions, we identified five main research areas and thirteen sub-research areas. Finally, we reflected on the content of the entire article and proposed a three-layer design framework that includes value judgment, artifact innovation, and people participation. We intend this article to offer inspiration in terms of specific details, general innovative direction, and methodological insights from the viewpoint of HCI to drive the innovation and revitalization of traditional crafts.

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