heritage

MDPI

Article

A Roadmap for Craft Understanding, Education, Training, and Preservation

Xenophon Zabulis [1,*], Nikolaos Partarakis [1], Ioanna Demeridou [1], Paraskevi Doulgeraki [1], Emmanouil Zidianakis [1], Antonis Argyros [1], Maria Theodoridou [1], Yannis Marketakis [1], Carlo Meghini [2], Valentina Bartalesi [2], Nicolò Pratelli [2], Christian Holz [3], Paul Streli [3], Manuel Meier [3], Matias Katajavaara Seidler [4], Laura Werup [4], Peiman Fallahian Sichani [4], Sotiris Manitsaris [5], Gavriela Senteri [5], Arnaud Dubois [6], Chistodoulos Ringas [7], Aikaterini Ziova [7], Eleana Tasiopoulou [7], Danai Kaplanidi [7], David Arnaud [8], Patricia Hee [8], Gregorio Canavate [9], Marie-Adelaide Benvenuti [10] and Jelena Krivokapic [10]

1 Institute of Computer Science, Foundation for Research and Technology Hellas (ICS-FORTH), N. Plastira 100, Vassilika Vouton, 70013 Heraklion, Greece; partarak@ics.forth.gr (N.P.); idemer@ics.forth.gr (I.D.); pdoulger@ics.forth.gr (P.D.); zidian@ics.forth.gr (E.Z.); argyros@ics.forth.gr (A.A.); maria@ics.forth.gr (M.T.); marketak@ics.forth.gr (Y.M.)

2 Istituto di Scienza e Tecnologie Della Informazione (ISTI), Consiglio Nazionale Delle Ricerche (CNR), Area Della Ricerca CNR, 56124 Pisa, Italy; carlo.meghini@isti.cnr.it (C.M.); valentina.bartalesi@isti.cnr.it (V.B.); nicolo.pratelli@isti.cnr.it (N.P.)

3 ETH Zurich, Raemistrasse 101, 8092 Zurich, Switzerland; christian.holz@inf.ethz.ch (C.H.); paul.streli@inf.ethz.ch (P.S.); manuel.meier@inf.ethz.ch (M.M.)

4 Khora Virtual Reality Høkerboderne 8, 1712 Copenhagen, Denmark; matias@khora.com (M.K.S.); laura@khora.com (L.W.); peiman@khora.com (P.F.S.)

5 Centre for Robotics, MINES ParisTech, PSL Universite, 60 Boulevard Saint Michel, 75006 Paris, France; sotiris.manitsaris@mines-paristech.fr (S.M.); gavriela.senteri@minesparis.psl.eu (G.S.)

6 Histoire des Technosciences en Société, Conservatoire National des Arts et Métiers (HT2S-CNAM), Case 1LAB10, 2 rue Conté, 75003 Paris, France; arnaud64.dubois@gmail.com

7 Piraeus Bank Group Cultural Foundation, 10558 Athens, Greece; riggasch@piraeusbank.gr (C.R.); ziovaai@piraeusbank.gr (A.Z.); tasiopouloue@piraeusbank.gr (E.T.); danae.kaplanidi@gmail.com (D.K.)

8 CERFAV, Rue de la Liberté, 54112 Vannes-le-Châtel, France; david.arnaud@cerfav.com (D.A.); patricia.hee@cerfav.fr (P.H.)

9 Technological Centre of Furniture and Wood of the Region of Murcia, Perales s/n, 30510 Yecla, Spain; g.canavate@cetem.es

10 Madineurope SCRL, 116, rue Berckmans, 1060 Brussels, Belgium; madina.benvenuti@madineurope.eu (M.-A.B.); jecakrivokapic9613@gmail.com (J.K.)

* Correspondence: zabulis@ics.forth.gr; Tel.: +30-281039-1696

check for updates

Citation: Zabulis, X.; Partarakis, N.; Demeridou, I.; Doulgeraki, P.; Zidianakis, E.; Argyros, A.; Theodoridou, M.; Marketakis, Y.; Meghini, C.; Bartalesi, V.; et al. A Roadmap for Craft Understanding, Education, Training, and Preservation. *Heritage* **2023**, *6*, 5305–5328. https://doi.org/10.3390/heritage6070280

Academic Editor: Andreas Aristidou

Received: 2 June 2023
Revised: 10 July 2023
Accepted: 12 July 2023
Published: 13 July 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Abstract: A roadmap is proposed that defines a systematic approach for craft preservation and its evaluation. The proposed roadmap aims to deepen craft understanding so that blueprints of appropriate tools that support craft documentation, education, and training can be designed while achieving preservation through the stimulation and diversification of practitioner income. In addition to this roadmap, an evaluation strategy is proposed to validate the efficacy of the developed results and provide a benchmark for the efficacy of craft preservation approaches. The proposed contribution aims at the catalyzation of craft education and training with digital aids, widening access and engagement to crafts, economizing learning, increasing exercisability, and relaxing remoteness constraints in craft learning.

Keywords: traditional crafts; craft education; craft training; craft preservation

1. Introduction

A roadmap towards the understanding and digital documentation of crafting actions and activities is proposed. A roadmap is required because understanding making activities that include *"care, judgement, and dexterity"* [1] call for interdisciplinary contributions from anthropology, cognitive science, art history, as well as physical and computational sciences to cover the multifaceted expression of crafts as living and developing heritage, as a source of income, and as the expression of the mind through *"imagery, technology, and sedimented knowledge"* [2].

The problem is challenging due to the multifaceted nature of crafts, which covers a wide range of both tangible and intangible dimensions [3]. The proposed roadmap recommends ways towards the documentation and sustainable preservation of crafting techniques. Motivation stems from the declining numbers of craft practitioners and apprentices [4] due to a lack of awareness, difficulties in knowledge transmission, and economic demotivation due to the lack of certificates and accreditation of qualifications [5].

Craft refers to the practice of making things using hands and tools. It involves the use of techniques, tools, and materials to produce objects, often with a high level of skill and attention to detail. Craft products are produced in small quantities, emphasizing the individuality and uniqueness of each piece. Pye [1] defined *"work of certainty"* as the predetermined actions outside the control of the operative and the "work of risk" as actions that depend on practitioner care, judgement, and dexterity. Tools of certainty are molds, hand presses, looms, stabilizing jigs, and measures, while tools of risk are scissors, knitting needles, chisels, paint brushes, etc.

Computer-aided craft education and training are proposed to widen access, economize learning, increase exercisability, and relax remoteness constraints in craft learning. The proposed roadmap aims at the catalyzation of craft education and training supported through immersive aids, craft simulators, and advanced, as well as high-end digitization and visualization. These tools are planned to widen access, economize learning, increase exercisability, train attention to safety rules, and relax remoteness constraints in craft tutoring. Immersive interfaces are recommended as central in providing virtual craft experiences due to the practical nature of crafting. As such, the integration of haptics into these experiences is important to train craft actions and make explicit the tacit knowledge employed in handiwork.

The simulation of crafting workflows is proposed to support material savings, part reuse, and reduction in energy consumption. The purpose of a simulation is to predict the result of new techniques of individualized tasks for part-specific operations. Safety is important for the training of adult practitioners, but even more important for younger ages. Today, workshop entry is prohibited for children. On the other hand, skills are more easily developed when young and traditionally, craft skills were acquired during apprenticeships at early ages. Therefore, realistic craft games and toys can interest and provide exercise opportunities with safety from an early age. Last but not least, the proposed roadmap targets social benefits that stem from the role of art and culture in our lives. Craft practice is increasingly recognized as a positive influence on personal and communal well-being when used as a vocational, leisure, and social activity [6].

The proposed roadmap stems from the implementation plan of a three-year research project on traditional craft preservation funded by the European Commission under the Horizon Europe Programme called Craeft, named after the old English term that means art, force, and skill. The purpose of this work is three-fold. First, it provides an overview of objectives and activities that exhibit the potential to contribute to craft preservation. Second, it contributes to policy and decision-making and provides product authentication and material provenance. Third, it serves as a resource for individuals or organizations interested in craft preservation by exposing the proposed approach, methodology, and techniques to criticism by the scientific and heritage communities, as well as to avoiding duplication of efforts by other peers.

To achieve the aforementioned goals, literature from multiple relevant disciplines is reviewed in Section 2. Technical, educational, and training recommendations, followed by business and policy proposals towards craft preservation, are provided in Section 3. In Section 4, validation and evaluation plans are provided. In Section 5, conclusions and future outlooks are outlined.

2. Related Work

The ambition of this work is to advance the understanding of crafting activities as an intellectual and physical process that employs perceptual imagery, knowledge, and technology. By formalizing this understanding, we wish to better document, study, teach, preserve, and develop crafting skills, transmit this knowledge for posterity, and use it for the prosperity of craft communities.

2.1. Data and Knowledge Collection

In 1990, UNESCO published a data collection guide for the documentation of traditional crafts [7], identifying the essential elements to be recorded: artefacts, materials, tools, and the crafting process. Photographic documentation was deemed necessary to record the practicalities of the crafting process, such as the way to hold a tool and manipulate it. Since then, digital photography and cinematography have advanced the state-of-the-art documentation of CH. The types of recordings and their individual recording parameters must be adjusted to the craft of the study. We review the main recording technologies, classified as to their use in the digitization of physical items, events, and documentation.

2.1.1. Data

Physical items are objects that remain static in time. In formal ontology, they are called endurants or continuants, meaning that their observation is the same at any moment in time. In the context of crafts, they are materials, tools, machines, products, information carriers, and sites. Recording of endurants is achieved through photography [8,9] and 3D reconstruction [10]. Comprehensive guides in the photographic recording of cultural heritage (CH) artefacts and sites are recommended for this purpose [10–21]. Additionally, methods for the digitization of challenging materials such as transparent objects have been proposed [22,23]. In [10], an approach to the full scope of 3D data curation through the collection, processing, archiving, and distribution of multiple modalities is proposed. A special case of endurants is information carriers such as books and manuscripts. Their primary digitization is photographic. Subsequent analysis regards the extraction of their verbal content conventionally through pattern recognition (OCR) as well as more advanced methods targeting manuscripts [24,25].

In the digitization of intangible cultural heritage, efforts tend to focus on phenomenological digitization, targeting the recording of kinetic or vocal activities [26–31]. Cinematographic and 3D motion digitization enable the recording of performing arts in multiple media and formats, exhibiting immersive qualities and interactive experiences [32,33] similar to musical content [34]. MoCap and Computer Vision are used to capture articulated human motion in 3D, documenting body motion in dance and theater [35,36]. In crafts, motion capture is employed for the investigation of crafting gestures [37].

2.1.2. Knowledge

Verbal reports aim to access the cognitive processes behind actions and can be carried out either online, with the reporter talking as they work, or offline, where the reporter comments retrospectively on their performance, often prompted by an audio or video recording [38,39]. A key limitation is the articulation of the reporter [40], as the reporter might not talk about what seems obvious to them, or they might alter their performance because they are aware they will have to describe it [38].

In [41], it is recommended to create event logs for each recording session as soon as possible after it. This urgency stems from the degradation of human memory, particularly when introduced to a plethora of events and details. The logs promote immediate reflection and a summary of actions that assist in later assessment and comprehension. The logs should summarize activities and short-term observations to create a narrative of the proceedings rather than a complete record. This has two outcomes: (1) an immediate review of the session that would inform the next stage of the research and (2) facilitation of a subsequent review of the material. In [42], it is proposed that logs can help to search digital records by content using a keyword search in the logs.

Interviews are widely used methods, but they are retrospective and dependent on human memory. Unstructured interviews are useful for establishing rapport and an overview of the activity but can result in large quantities of data [38]. Structured interviews, where the same predetermined questions are posed in the same order, provide more manageable data but require a deep knowledge of the domain and are time-consuming to prepare.

2.2. Ethnography

Ethnography [43] identifies and describes the activities of social groups and their members as "textual reconstructions of reality" [44]. After the advent of digital imaging, the ethnographic study of crafts was modernized by Wood [41] to include digital recordings. Recently it has been applied in workshops, with examples in carpentry [45], glasswork [46], and textile manufacturing [47].

The interaction between the actions of the maker and the type, properties, and individualities of the material is described as a negotiation [48,49] between the maker and the material. It is further identified as one of the reasons for the uniqueness of craft products. From the perspective of material agency, it is argued that craft practice is the result of a negotiation between the material and the maker and that the bodily movements of practice emerge from this dialogical act. In these works, it is recommended to investigate craft processes from a perspective that uncovers how crafting actions occur through bodily movements and material transformations. The emergence of the artefact is studied with a focus on the relationship between the maker, material, and practice. This examination enables an understanding of what happens in each contact moment between the maker and the material.

Short-term ethnography [50] is an alternative to the traditional format that permits a shorter length of fieldwork activity in return for intense engagement between the researcher and their participants. The rich points that make up an ethnographic account need to be actively sought in short-term ethnography. This can be achieved by utilizing the prior construction experiences of the researcher. The researcher enters the field with an emic insight that can be used to seek out events and allows the production of meaningful ethnography from a shorter, more intense fieldwork period, learning much from individual workers before they move on. Engagement extends beyond onsite interactions through the use of video to record everyday activities by introducing attention to reflexive ethnographic practice.

A recent craft ethnography method is that of [45], where it is argued that ethnography has much to learn from artisans in order to advance the vision of artisan-inspired ethnography. This work investigates what artisanal ethnography should be like, treats artisans as ethnographic educators, and determines its tools, goals, and guiding principles.

2.3. Descriptions and Representations

Craft taxonomies are primarily material oriented [6] and, at a secondary level, classify materials by origin. This classification does not facilitate the understanding of crafting actions, as similar actions can be exercised on materials of different classes.

Craft descriptions are available for many crafts and in several formats. For example, weaving instructions for mechanical were introduced in illustrated manuals in the 19th century [51], instructions for glassblowing in the format of a graphic novel (comic) can be found in [52] while, more recently, narrated videos for crafting can be found in several popular video repositories online. A characteristic of this material is that it is oriented to a specific craft, and, as such, a generalizable way to produce craft descriptions and instructions is yet to be found, albeit many crafts share similar principles and actions.

Craft descriptions are classified into thin and thick. Thin descriptions are phenomenological observations of behavior. Thick descriptions include explanations of how these behaviors are interpreted by the participating actors. These explanations include descriptions of intention, attention, judgement, and action modulation [53].

The representation of intangible dimensions of traditional crafts as processes were proposed in [54]. In [55], it was proposed that craft representations should include semantic descriptions of crafting plans and processes associated with recordings of these processes. These approaches use activity diagrams to represent process steps that transform input materials into output products for each step.

2.4. Cognitive Studies

Cognitive studies in this context aim to examine the cognitive processes involved in traditional crafts, such as mental representations, problem-solving strategies, and expertise development. The focus of these studies is the understanding of how craft knowledge is acquired, organized, and transmitted, as well as how individuals acquire and develop expertise. Moreover, cognitive studies focus on revealing the processes underlying skill acquisition, perception, memory, attention, and problem-solving [56–60].

The perception–action circle is a means of identifying the phenomena taking place during an action [61]. The perception–action cycle is the circular flow of information from the environment to sensory structures, to motor structures, back again to the environment, to sensory structures, and so on, during the processing of goal-directed behavior [45]. The circle is comprised of four iterating stages: perception, prediction, action, and outcome. This conceptualization has been used to achieve robotic perception and actuation [62–64], and naturally, it applies well to crafting actions. We take good notice that this circle is a conceptual tool and that attention is not passive but active, while also understanding that actions give rise to additional perceptual stimuli. This is because the practitioner engages the world through the interpretation of sensory images and not direct measurements of the world. As such, experiments and observational studies are required to investigate how practitioners perceive and interpret materials, plan and execute motor actions, and engage in problem-solving.

2.5. Simulation

Simulation studies have been used to understand and analyze various aspects of traditional crafts, including their production processes and material behavior. These studies aim to gain insights into craftsmanship, improve techniques, and preserve cultural heritage [65]. Focus is placed on modeling material behavior during crafting actions and the impact of action parameters. These studies also aim to understand how different tools and techniques affect the final product, optimize material usage, and reduce waste. An important part of the simulation is the prediction of the behavior of materials under specific action parameters, allowing the optimization of techniques.

Mechanical simulation is used in industrial manufacturing to reduce human effort, energy, and materials. Finite element analysis [66] is the most widely used method in mechanical simulations. To solve a problem, finite element methods partition systems into smaller and simpler parts (finite elements). This is achieved by space discretization, usually implemented by a mesh for each object involved. The method results in a system of algebraic equations applied to predict the behavior of each element.

Craft simulators exist as digital games and are usually simplified as "play the carpenter" games for mobile devices. Woodwork Simulator [67] introduces carpentry tools and their function and accounts for action parameters (e.g., force) and material properties. A review of craft simulation in games that includes an assessment of the realism of simulation can be found in [68].

2.6. Training and Design

Vocational training employs digital asset annotation and workspace simulation. The need for visual annotation upon photographic documentation, particularly in handicrafts, is identified in [69]. Mixed reality (MR) and virtual reality (VR) environments are used to train professionals in manual tasks. Human motion is used for workspace design [70]. Avatars are employed in manual task collaboration [71]. VR is employed in maintenance training [72]. Immersive storytelling has also been proposed for training [73].

Research efforts have focused on introducing innovative design tools to architects [74,75], studying historical design and patterns as a source of inspiration and craft preservation [76–78]. Traditional crafts in informal intergenerational knowledge transmission often have a specific focus on product type and regulated style. The industry creates novel design elements and styles, which are applied to multiple products, often drawing inspiration from local tradition. Applied Art and Design schools stand in the middle offering traditional and novel technique learning. The core ideas implicit within the Bauhaus are reimagined, retrofitting them for the modern age and its challenges [79–82].

2.7. Sustainability

Immersivity and storytelling have been employed in CH engagement to create compelling and memorable experiences, including location-based interactive presentations and experiences [83,84]. Some of the attempts include combining 360° video with storytelling [85], using immersivity to present maritime and underwater heritage [86], employing emotions to enhance narrations on CH subjects [87,88], presenting stories that are part of the intangible heritage of a community [89], and simplifying the design of immersive CH presentations [90]. In the same context, other research efforts were focused on the development of virtual guides with an emphasis on realism, emotional sensitivity, and meaningful dialogue [91,92].

Existing work on the sustainability of CH collections and sites focused on connecting CH collections in sustainable management [93], empowering CHIs with financial strategies [94], assessing the socio-economic impact of digitization of CH goods and services [95], providing business models for inclusive growth [96,97], creating cultural routes, promoting local and sustainable materials, energy-efficient production, attachment of "green" certificates on products, and reducing training costs, energy, and material footprint using immersive technologies and telepresence tutoring.

3. Method

Phenomenological recording (see Section 2.1) is sufficient for the reproduction of content but is not sufficient for understanding the experience of the performer or practitioner. To record this experience, we recommend representing crafting actions rather than only motions. That is to thicken the ethnographic description with entities and quantities found in the mechanical and cognitive domains, as these have been specifically identified in the following domains of the literature:

- Physical and mechanical events involving motor-induced actions concerning the crafting workspace and materials;
- Cognitive events involving mental activities for the perception of the environment, including predictions regarding possible actions, plans, and judgements.

Moreover, visual and semantic documentation is still distant. To better understand and document crafting action, we recommend the semantic representation of the aforementioned quantities and entities. We recommend using the MOP infrastructure [55] to document craft instances in steps, associating phenomenological action recordings with verbal descriptions.

3.1. Overview

In the context of this work, actions refer to the processes or acts of doing something related to the creation of a craft product, according to the current situation, intention towards creating a specific product, or aesthetic desire. Actions involve the execution of physical, mental, or verbal activities to achieve a goal. Actions can be conscious or unconscious, and they can be performed by individuals or groups. Movements of the hands and body within the context of physical actions are referred to as gestures. In the context of physical actions, action parameters refer to variables that influence them. These parameters provide details about how an action is performed, including properties that affect its execution, such as speed, force, direction, and duration. Crafting actions upon materials are mediated by tools and/or hands. Actions are events [98].

The goals of crafting actions refer to the intended outcomes that practitioners seek to achieve through these actions. Mental imagery is central to goals and enables the visualization and mental simulation of intended actions and outcomes. It involves mental representations of actions without their physical execution. Goals are encoded in mental imagery as the result of mental simulation, planning, or prediction.

Action plans refer to sets of organized steps designed to achieve a goal. They outline the actions required to accomplish a goal. These plans provide a structured approach to problem-solving, decision-making, and implementation of action. Moreover, action plans regard hypotheses for the achievement of goals, such as the prescribed conditions on the state and spatial arrangement of materials and tools. Action plans indicate affordances, availed by working spaces, the human body, and tools, as well as agents of heat, moisture, chemical reaction, or color pigmentation. Action plans prescribe the mechanism and the parameters of execution. Special plans are made to handle errors.

We refer to the perception–action circle (see Section 2.3) to conceptualize crafting actions. Our interpretation is illustrated in Figure 1 and is as follows. During a physical action, the practitioner attends to external (sensory) and internal (somatosensory) stimuli that inform the course of the action. Due to action, more stimuli are generated. The practitioner modulates action parameters accordingly. Mental imagery envisages the anticipated sensory imagery, should the goal be achieved. The result is attended in perceptual imagery created by the senses and judged against mental imagery associated with the action goal. After an action, the practitioner compares mental and sensory imagery and updates or reconfirms the action parameters. Upon completion of a process, the practitioner reflects on its course and outcome and may update it.

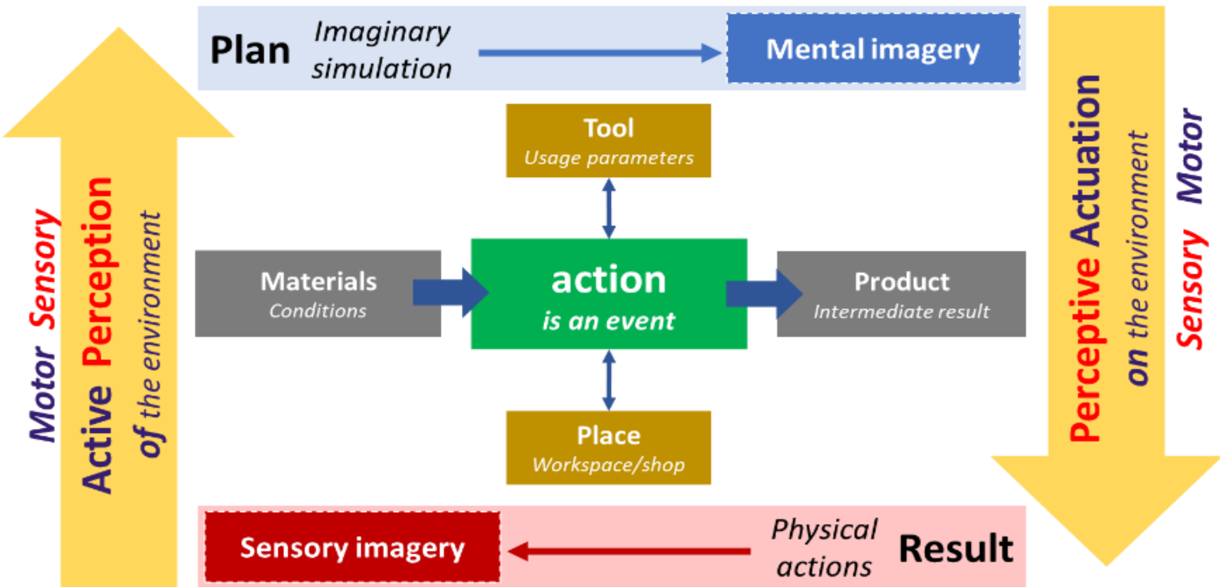

Figure 1. An interpretation of the perception–action circle for the understanding of crafting actions.

A crafting process is defined as the combination of actions in an "umbrella plan" [2] called process schema or crafting activity. The proposed model brings forward the role of prediction and mental imagery in the formation of action plans. An action model suitable for representing crafts should be able to generate predictions or otherwise mental imagery [2], which predicts and explains action execution and action results.

3.2. Data Collection

The collection of knowledge on craft practice and the corresponding digitization of tasks require the capture of observations that target the physical, bodily, and intellectual entities involved. The basic means of this type of data and knowledge are verbal and visual records of practitioners, in the form of testimonies and digitizations, respectively (see Section 2.2). This task exhibits interdisciplinary requirements. Anthropologists and cognitive scientists must identify observations and interviews to describe the aforementioned craft elements in an explanatory fashion; that is, to identify and describe sensory, tacit, and intellectual entities. Information scientists will then model these entities as knowledge classes and instances. In addition to the recordings described in Section 2.1, we propose enhancing the recordings with data that foster the generative explanation as follows:

- Physical properties that represent the mechanics of crafting actions upon materials;
- Cognitive properties related to attention and control.

Understanding crafting actions as the negotiation of the maker with the material calls for the enhancement of data collection with recordings that capture the quantities, properties, and behavior of objects and materials involved in crafting actions. To achieve this goal, the collection of the following data and descriptions is recommended.

3.2.1. Material Properties

Conventional digitization methods for tangible heritage include visual 2D, $2\frac{1}{2}$D, 3D, and 4D digitization of tools, products, and human motion (see Section 2). Digitizing tangible heritage comes with challenges and limitations that need to be considered. These include ensuring accurate measurements, managing data storage and processing demands, and the requirement for specialized equipment and expertise. Exploring these aspects provides a more balanced understanding of the digitization process. Pertinent signals include surfaces, anaglyphs, solids, tool motion, material deformation, sounds, as well as heat, humidity, and other environmental properties.

Material properties are crucial in the conservation and restoration of cultural heritage artefacts. Preservation efforts require a deep understanding of the original material properties to ensure appropriate treatment and maintenance. For instance, understanding how materials are susceptible to environmental factors such as humidity, temperature, or light helps conservators establish proper storage conditions and develop conservation strategies to prevent damage or decay. Material properties contribute to the authenticity and accurate replication of cultural heritage artefacts. When recreating historical objects or traditional crafts, knowledge of the original material properties is essential to achieve faithful reproductions. Thus, the selection of material properties of relevance is craft-dependent. Material properties can be extensive or intensive. Intensive material properties do not depend on the amount of the material and may be mechanical (e.g., brittleness, ductility, hardness, plasticity, and viscosity), manufactural (e.g., castability, machinability), but also acoustical (e.g., absorption, speed of sound, and sound reflection), or other. Extensive material properties may include mass, volume, heat capacity, temperature, velocity, tension, and others. Material properties are quantifiable and, thus, can be estimated from measurements or approximated from libraries. Capturing the properties of individual pieces of material and tools enables us to study closer how the same action is instantiated and how the same action is parameterized to cope with the individualities of each piece of material. Dynamic material properties vary over time and refer to the object's motion, material deformation, and modal materials properties, such as stiffness, viscoelasticity, and others. They can be initially approximated from open libraries (e.g., [99]) or measured. To capture the temporal expression of these properties, a time-dependent representation is required.

3.2.2. Action Properties

Action properties refer to the parameters of the practitioner's actions, such as grip and body postures, crafting gestures, as well as the motor activity of the practitioner. Typically, these parameters are dynamic because they refer to practitioner motion and action, though sometimes they may remain constant, such as a tool grip. Practitioner motion is captured by vision-based marker systems, vision-based markerless systems, and wearables. However, these technologies do not necessarily reveal the amounts of force and effort of the practitioner; for this, we recommend the use of force or tension measurements. This can be directly achieved by pertinent gauges or the use of wearable haptic recorders. Indirectly, they can be estimated through the result of the action on the material, given that pertinent physical properties are provided. Indirect descriptions can be based on data that reveal human effort, such as facial expressions, posture, or even sweat. Training datasets are recommended to associate the semantic representation of actions with the recordings of their material expression (practitioner force and motion, tool manipulation, artefact appearance and geometry, material transformation, and perceptual annotations). The purpose is to bring the semantic and visual representations closer so that similar examples can be associated but also to create semantically annotated datasets from which the computer can learn action representation.

3.2.3. Cognitive and Embodied Properties

Capturing and conveying the practitioner's viewpoint call for the identification of the perceptual and action elements of crafting actions. Plans are also entities of interest and include the execution of cognitive actions such as prediction and judgement. Cognitive events are not directly observable; thus, their digitization is not simple. Attention to environmental and somatosensory stimuli is an integral part of craft education and training. Environmental stimuli can be recorded in conventional ways, as we can record pertinent events from the environment using the aforementioned techniques. Environmental stimuli can reveal details about crafting actions, such as sound in material processing or inspection. For this reason, data collection should capture environmental stimuli that relate to the use of sensory perception in crafting actions. The representation of somatosensory stimuli can lead to the identification of environmental events that the practitioner pays attention to. The most challenging entities to capture are sensations and perception because they are "private" and cannot be recorded directly. However, memories of internal signals (qualia) [100] can be verbally testified and recognized out of simulated imagery generated by audio, visual, or haptic rendering. The notion is similar to facial composition software, where by tuning parameters, the memory of a face can be synthesized. The particular rendering is then a digitization of the sensory imagery the practitioner "feels" [101].

3.3. Understanding

A hybrid, semantic, and functional representation of the recorded crafting activities is proposed. This representation combines the collected data with the semantic interpretation of actions and with mechanical models of their function. The goal is to use semantic annotations provided by practitioners to classify craft actions into types of mechanisms and identify environment features and action parameters of relevance. In ethnography, semantic interpretations will be requested from practitioners along with an explanation and identification of the mechanical models to functionally model crafting actions. Making sense of the recordings requires fitting the collected data and representations into interpretations that explain the recorded actions and are collected by measurements. The interpretations should primarily identify the type of mechanical affordance, the material properties of relevance, and its execution parameters. The latter includes properties such as force, timing, angle of attack, 3D shape, grip posture, and other pertinent properties.

3.3.1. Semantic

The semantic modeling of craft actions is based on a craft-specific ontology obtained by extending the MINGEI ontology [55] with classes and properties needed to model the sensory and mental imagery used in crafting actions. The ontology is implemented on an online platform that extends the MINGEI Platform [55]. The ontology is an extension of the ISO standard CIDOC CRM [102], a vocabulary extensively used for representing

CH by the major European GLAMs (galleries, libraries, archives, and museums). In particular, we reuse some CRM classes and properties for modeling fundamental notions and add our own as refinements of those in the CRM, for modeling concepts and relationships that are specific to the craft application domain. To increase interoperability, we also use standard terminologies whenever possible. In particular, given its richness, multi-linguicism, and widespread adoption from the CH sector, the Getty thesaurus is adopted [103]. Furthermore, this thesaurus includes a comprehensive collection of action labels. Nevertheless, the platform allows the use of any other online dictionary or thesaurus, such as the one provided by UNESCO [104] or others provided by national authorities. Thus, a knowledge entity can be associated with multiple meta-data from multiple sources in the proposed implementation.

3.3.2. Functional

To reduce the complexity and enable the scaling of the proposed approach, we recommend creating an ontology able to represent the elementary actions that are common in all crafting actions. Observed actions will be modeled as configurations of elementary ones. The elementary actions are identified by the analysis of the mechanisms of interest into simpler, archetypal mechanisms. In particular, actions are classified into add, subtract, interlock, or transform operations (see Figure 2). Materials are correspondingly classified by compatibility with practitioner actions as free-form (plastic) materials that take any shape, fibers interlocked into fabrics, and solids that are reduced to a subset of their original volume. A notable subclass of 3D solids is 2D surfaces. Some crafts combine actions and materials of diverse types, as in the crafting of musical instruments.

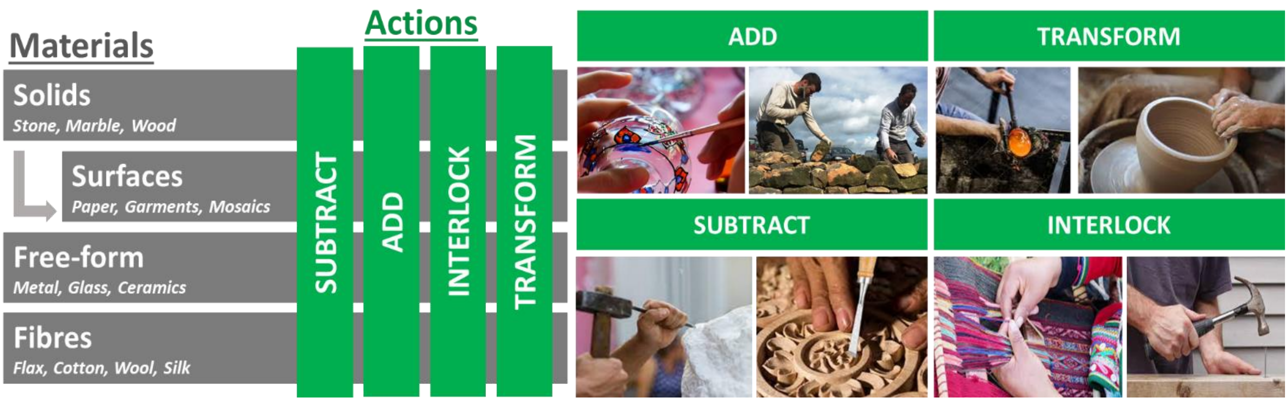

Figure 2. Classification of actions and materials.

We follow the craft ontology [55] to represent knowledge entities for actions and extend it so that actions include the tools, materials, and products of each action. Tools are modeled as affordances to cope with the fact that diverse tools can provide the same functionality and that a single tool may also avail multiple functionalities. For example, a nail can be driven into wood with a hammer or an adz, while pliers can be used to drive a screw or cut a wire. Affordances are modeled as Archimedean simple machines, which comprise a small and simple vocabulary that can model all mechanical tools.

As actions are events, the representation of the knowledge obtained from recordings of craft practice is used in the instantiation of these entities. The interpretation and analysis of these recordings provide direct input to the instantiated entities, as the analysis of recordings can reveal the action parameters used. For example, computer vision algorithms disentangle such properties by learning appearance across the modulation of contextual properties. Generation disentangles such properties and encodes material appearance in disentangled space to predict appearance. Existing approaches learn embeddings for 3D objects, mass-preserving transforms from structural constraints (connectivity and stability), texture transfer, and differentiable rendering [105–108].

3.3.3. Cognitive

The term sensory imagery refers to all senses and not solely vision [2]. Practitioners use their senses to acquire information concerning material properties and events. Mental imagery is the mechanism by which we mentally simulate perceptual experiences and refers to the sensory images of the "mind's eye" (or finger, ear, etc.) [2]. Sensory imagery, or qualia, are sensed, e.g., "hand-feel", softness, and smoothness, can be recognized, and recalled as mental imagery, such as when thinking about the color of amber, the feel of satin, or the timbre of the oboe. Action plans are formulated as generative hypotheses that can be used to simulate "mental images" of the anticipated results. Their representation of both has a pedagogical value in the training of crafting actions and particularly in the "education of attention" [109].

3.3.4. Validation

Part of the proposed methodology is close collaboration with practitioners and the co-creation of obtained knowledge with them. This is a critical point in the validation of the obtained knowledge. For this reason and as dictated by the Mingei protocol, each step of this approach is co-designed with practitioners and validated afterwards with them. In this work, this requirement is taken a step further by involving craft tutors in the co-design of educational and training curricula. To ensure the validity of knowledge collection by craftspersons, the proposed roadmap recommends the engagement of craft tutors that shall enable the explanation of recorded actions. This task is planned to take place in three temporal stages. The first regards an interview before the recording where the craft master shall explain the actions to be performed. The second regards the ability of the craftsperson to explain the actions during this recording. This particular step is to be encountered with great caution as explaining while performing may alter the performance of the crafting action. Third, and most importantly, the practitioner shall watch the recording with an ethnographer to clarify the actions performed in the recording and ensure the validity of the ethnographic representation.

3.4. Simulation

A way to validate and better understand crafting is simulation. Simulation has a significant role in both education and training because validating the understanding of a cognitive process is the ability to recreate it [110]. The inclusion of simulation is two-fold. The first is to recreate the prediction process or the practitioner's planning. The second is to use the simulation as an educational, training, and design tool. To simplify implementation, we model actions to be comprised of elementarily, each one defined by an "archetypal" simulator that implements the action principle. The implementation of each craft-specific simulator will be based on the instantiation of archetypal simulators according to the parameters implementing each case. The simulation result, a realistic virtual artefact, is regarded as simulated mental imagery.

It is important to ensure that the simulated results align with real-world outcomes. Simulating this real-time adaptability and responsiveness can be challenging since the interactions between different materials and their dynamic responses can be complex, especially when considering non-linear material behaviors or variations in material properties.

3.4.1. Archetypal Simulators

Archetypal simulators are used to digitally re-enact the basic classes of actions, abstracting mechanics via computational modeling. They are based on existing mathematical abstractions for the operation principles regarding (1) add/subtract by constructive solid geometry, (2) interlock by knot/textile algebras, and (3) free-form by mass-preserving, free-form 3D and 2D transforms [111–114]. Achetypal simulators model mechanical affordances as Archimedean simple machines [115] (e.g., a knife is a wedge) or physical and chemical (conditioning) agents, i.e., heat, moisture, chemicals, etc.

3.4.2. Craft-Specific Simulators

Archetypal simulators are instantiated into craft-specific simulators by estimating the relevant range action parameters and predicting the results. Craft-specific simulators visualize techniques, enable modulation of action parameters, space, and time, offer inventories of tools, and predict the results of the action on the material. An example of a subtractive operation is illustrated in Figure 3.

Figure 3. Similar material subtraction actions across different crafts.

Two approaches are evaluated for the implementation of refining archetypal simulators into craft-specific simulators. The first is to model physical and mechanical laws using finite elements. The action parameters and material properties for the instantiation of an archetypal simulator will then be provided from the data collection task (see Section 3.1). The second is to use machine learning to simulate actions from annotated datasets. Generative learning methods, such as variational autoencoders and generative adversarial networks [116–119], create novel text, images, and videos from training data. In crafts, estimators for articulated hand motion for hands that manipulate objects use annotated datasets to create simulators that can be refined with additional data for similar actions on diverse materials [120–122] to realistically decompose and simulate pose, shape, texture, and lighting.

Simulation developers can practice their techniques, experiment with different materials and tools, and refine their skills without the risk of damaging physical objects or wasting resources. They can explore different design possibilities, evaluate material choices, and visualize the outcome of their actions. By digitally recreating the crafting process and understanding the material properties involved, conservationists and restorers can develop appropriate conservation strategies. Simulators can be utilized in the design process to explore different variations and possibilities, aiding in the creation of innovative craft products or techniques.

3.4.3. Implementation

The software that will host the design of simulators will be called Craft Studio and will be used to instantiate craft-specific simulators from archetypal simulators. Craeft Studio will be an authoring platform where action simulators will be combined into process simulators, organizing actions and bringing together partial results, considering fabrication constraints (e.g., order, concurrency, and decision points) and spatial constraints of the workshop. In this context, state-of-the-art methods for the simulation of dynamic environments incorporate differentiable physics for actions on non-rigid objects and long-horizon tasks [123,124]. Craeft Studio will be used to provide simulation analytics that log the material quantity used or wasted and the energy and time spent. A challenge is the computation of FEMs that could hinder the real-time execution of interactive simulations. However, this can be countered by precomputing results for a range of parameters and invoking the appropriate ones based on user input.

By simulating the behavior of materials and structures, developers can identify areas of potential weakness, inefficiency, or excessive material usage. Simulation developers and analysts can make informed decisions regarding the most suitable materials that meet their requirements while minimizing waste and maximizing efficiency. Simulation developers can identify areas where material waste occurs or where process inefficiencies exist.

3.5. Education

Craft education regards theoretical craft knowledge, which includes tool inventories, material conditions and properties, material preparation recipes, and, in general, the knowledge that can be acquired by verbal communication. Simulation environments can be used to create educational courses with e-learning capabilities. These courses introduce vocabulary, material treatment, workspace configuration, measurement tools, and, ultimately, crafting processes. The association of semantic annotations with digital assets can be used to generate verbal descriptions and instructions that are illustrated with visual examples. The purpose of 3D and immersive illustration is to place focus on "skilled monitoring" or otherwise *"the ability to evaluate changes brought by practitioner actions and decide if they conform to images of how the work should look at any given stage of production"* [1]. The motivation is to develop critical thinking and judgment on treating craft as a problem-solving process, covered by principles of continuous design [125]. Educational material acknowledges mistakes and uncertainty as part of skill development. Specifically, commonly occurring errors and their handling are often included in this material.

"Declining numbers of practitioners and apprentices" [1] are due to a lack of awareness, difficulties in knowledge transmission, and economic demotivation due to a "lack of certificates and accreditation of qualifications, particularly for high-quality training and standards of practise" [5]. Certification and skill acknowledgement educational programs will be aided by the adoption of digital aids in knowledge transmission. To acknowledge educational and training experience, we recommend using the Proof of Attendance Protocol [126], a standard by which projects can award personal ("soulbound") badges that represent participation in events with a role (e.g., students and instructors).

3.6. Training

Mastery, tacit or embodied knowledge [127], and perception are recognized as the skills to *"move work as quickly as possible with a minimum of physical errors"* [2]. The way people master skills is through repeated practice. Central to the development of dexterity are the experience of performing motor actions and learning interpretations of stimuli. The main interface for training exercises will be an immersive software environment called "Apprentice Studio". Apprentice Studio will provide experiences that comprise craft-specific interactive educational materials. Visual immersive interfaces will include AR and VR. Various haptic feedback actuators will simulate the sensations created from the interaction of tools with materials across combinations of physical and virtual instantiations. The system will economize the development of monitoring and action skills by enabling (a) practice away from the workshop, (b) repeated practice on virtual materials, and (c) immersive telepresence of an instructor. Immersion will be used for safety training before visiting the workshop.

3.6.1. Action

Apprentice Studio will support exercises of crafting actions along with the provision of feedback. Training regards the development of dexterous manipulation for tools of risk. In handwork, tactile interaction is essential to achieve realistic and beneficial training experiences for training. To increase the immersion, realism, and efficacy of actions, the environment will support haptic interfaces in addition to conventional 3D multimedia and XR interfaces. This environment will support the training of action, coordination, and synchronization through opportunities for repeated practice, particularly for free-hand operations. A basic component shall be training on efficient and ergonomic handling of tools prescribed in these exercises. For this purpose, prior knowledge provided by literature will be incorporated for hand-driven tools [128]. To provide haptic interfaces for design tools to capture the delicacy of human touch, increase design possibilities, and prepare for actions to take place in the workshop, Craft Studio will be used as an audio, visual, and haptic rendering engine to develop a 3D virtual workspace for the design, manufacturing, and presentation of artefacts. Furthermore, it will integrate craft-specific 3D editing tools that will mimic actions on virtual materials.

3.6.2. Perception

Training attention regards learning to detect and attend to perceptual stimuli and interpret their meaning in the monitoring and control of the action at hand. These stimuli can be (a) external (e.g., audio/video), signifying material qualities, properties, and events, or (b) internal (e.g., proprioceptive and tactile), on awareness of hand and body posture, modulation of applied force/tension, incidence angle, etc. Haptic rendering will simulate inspective tactile sensing and feedback using simple hardware [129]. As bimanual coordination is crucial in the majority of tasks, we will draw ideas from bimanual haptic controllers. We propose the combination of haptics with immersive environments to introduce the affordances provided by hands and tools and their degrees of freedom and guide students through action variability on different pieces of material.

3.6.3. Time

Time awareness is central in many crafts due to the change in material properties over time (e.g., blacksmiths and glassblowers "think hot" as material viscosity decreases as it cools). Simulators will operate in real-time but can be retarded or accelerated for training purposes. Stress destabilizes the learning process [130]; thus, training simulators will "slow down the time" to ease the practical challenge, similar to music where practice initiates with a slow tempo. Finally, social interaction in the workshop is important for knowledge transmission. Craft materiality imposes a need for co-presence to teach the interpretation of stimuli. Communication is important because part of this knowledge is tacit and understood by the common stimuli shared by the instructor and apprentice.

3.7. Development

To support the design process of craft products, an authoring environment that enables the design of crafting workflows, the testing of new ideas, and the fabrication of material aids is proposed. The software that will implement this is called Design Studio and will employ computer-aided digital design and fabrication. The goal is to conserve practitioner time and to reduce energy and material consumption through the development of workflows and designs. In this context, we recall that the design and fabrication processes are interwoven; thus, Design Studio will support practitioners in exploring workflows that lead to the fabrications of an incepted or given design.

3.7.1. Design and Workflow

Design Studio will implement a "sketchbook" metaphor to support the creative process. Design Studio will employ computer-aided design for the development and testing of new ideas, techniques, and styles. This functionality will reduce experimentation costs, as it will include visualization of the results predicted by a given action or process, using the simulators of Craft Studio. The design process will be further assisted through the provision of craft-specific conventional design templates as well as style transfer [131] that may stimulate inspiration. Workflow implementation in Design Studio will emphasize the fact that craft products are often comprised of parts and pieces. This is important for the functional preview of designs as well as for the study and optimization of the crafting workflow. The goal is to improve the functional preview of craft products.

3.7.2. Digital Fabrication

Design Studio will incorporate design tools and drivers for digital fabrication. The purpose is three-fold. First, to provide the capacity to create fabrication aids. Second, to automate the fabrication of craft artefact parts that are simple to "print". Third, to explore possibilities of hybrid artefacts, e.g., [132]. To achieve this, Design Studio will interface with additive and subtractive manufacturing protocols and formats so that 3D models can be directly printed.

To achieve a realistic preview, the interaction of artefacts with lighting will be simulated using conventional computer graphics methods. Moreover, a True-AR infrastructure is recommended so that the predicted artefact appearance can account for the environment of the client.

3.8. Preservation

Craft preservation means the continuation of practice and, thus, the existence of motives to do so. The main motivator for producers of craft products is the increase in their income. We propose several ways to increase practitioner income through the divarication of their income streams.

3.8.1. Digital Dimensions

Linking craft products with online content or "digital dimensions" increases their value. These shall include the following. Creator signage and certificates of compliance with material composition naming and production principles, indicating aspects of design uniqueness, authenticity, and cultural heritage that they express, as craft products embody the cultural heritage, traditions, and stories of a particular region or community. Certificates of compliance with protection indicators, manufacturing legislation and regulations, as well as "green" certificates of production, material provenance, use of sustainable and ethical practices, incorporating eco-friendly materials, and use of fair-trade practices [133]. Moreover, contextualization content, in the form of narratives, will be provided to support storytelling regarding the product, its maker, the materials used, or the cultural significance. We recommend two ways to achieve this implementation. The first is through conventional means, such as barcodes or QR codes in the form of stickers glued on the product. The second is through visual recognition, either of the artefact's appearance or any type of signature or identifier inscribed by the creator upon the product.

3.8.2. New Products

Digital games and physical toys are recommended for the support of craft introduction, recreation, and the development of crafting capacities. Educational toys can be accompanied by instructions in paper or electronic formats. Combined with online courses, they can cultivate creativity and transmit the values of care, judgment, and dexterity, as well as local traditions for students and cultural visitors. Toys will be designed and developed in Design Studio, either simplified for younger audiences or designed to engage creative activities for elders. The digital blueprints of these toys can be marketed in printable formats or as electronic products. Digital games can be created by reusing craft-specific simulators to create simplified or serious games in the realm of electronic creation and design. Digital creations will be encoded in formats importable in common virtual worlds and metaverses used by both youngsters and adults. A benefit of such products is the simplified and 'safetified' introductory content enabling the training of practitioners before entering the workshop.

3.8.3. Tutoring

Craft tutoring supports practitioner income. We recommend the appropriation of conventional teleconference but also immersive telepresence to support tutoring services. In addition, the recording of workshops and masterclasses can be streamlined by authoring tools for educational material and skill development media compatible with hybrid participation [134]. This will be a valuable addition to "how-to" instructions and designs from dedicated SoMe, video repositories, and illustrated instruction repositories, e.g., [135], for creative recreation and to improve skills.

3.8.4. Recreation

Reward and motivation play crucial roles in crafting. Reward refers to the positive outcomes or incentives associated with completing a particular task or achieving a specific goal. Motivation refers to the driving force behind crafting. The following aspects are recommended to be addressed in applications targeting craft preservation.

Crafting activities can be driven by intrinsic and extrinsic motivation. Intrinsic motivation comes from internal factors, such as personal enjoyment, creativity, and a sense of accomplishment. Extrinsic motivation stems from external factors such as recognition, praise, or tangible rewards. As crafting activities are guided by goals, setting clear and achievable goals provides a sense of direction and purpose, enhancing motivation. Additionally, analyzing larger crafting projects into smaller, manageable tasks with specific milestones creates a sense of progress and accomplishment along the way, acting as intrinsic rewards that fuel motivation.

Regular feedback is essential for maintaining motivation during the crafting process. Feedback can come from personal evaluation, constructive criticism from others, or even the tangible results of crafting efforts. Positive feedback or visible progress acts as a reward, reinforcing motivation and encouraging continued engagement in the craft.

Crafting involves learning new skills and techniques. The desire to improve one's skills and achieve mastery in a craft is a motivator. As individuals see their skills progressing, they may experience a sense of accomplishment and intrinsic reward, fuelling their motivation to continue crafting and pushing themselves to new levels. Moreover, crafting can provide social rewards and a sense of belonging. Sharing crafted items with others, receiving compliments or recognition from peers [6], or participating in crafting communities and events enhances motivation and fosters satisfaction.

Reward and motivation intertwine in the elaboration of crafting actions. Rewards, whether intrinsic or extrinsic, help reinforce motivation, while motivation drives individuals to engage in crafting activities, set goals, seek feedback, develop skills, and find satisfaction in the craft.

4. Validation and Evaluation

Ways of validating and evaluating the efficacy of the proposed roadmap are proposed. A set of representative craft instances (RCIs) spanning the range of craft techniques will be used for this task. It is proposed that a collection of such RCIs should include glassmaking and pottery, as representatives of free-form actions, stone and metal sculpting, as representatives of subtractive actions, carpentry and metalsmithing, representatives of additive operations, as well as textiles and tapestry, as representatives of interlocking actions. Comparative studies regard actions that are employed in similar materials, such as pottery using clay and porcelain, material subtraction in the context of marble sculpting, silversmithing, and woodcarving, or interlocking fibers to create textiles, wicker, or tapestry.

4.1. Validation

To validate the generality and expressiveness of the approach, three pilots will cover a range of RCIs and compare them across similar techniques and materials employed in their context. The recommended pilots are focused on the following goals.

4.1.1. Preservation

While conservation regards digital documentation in international and open standards for digital libraries, preservation regards the continuation of the practice. The objective of this pilot is to catalyze the continuation of practice through craft education, training, and awareness. Central in craft preservation is the provision of education and training opportunities for new practitioners. This includes formal training programs, apprenticeships, workshops, and mentorship programs where experienced practitioners pass on their skills and knowledge to the next generation. The pilot should provide digital aids that are appropriate for the training program of RCIs. The enhanced program will be evaluated in comparison with the training programs of RCIs and improved based on feedback. Validation will assess the efficacy of the developed training materials by measuring the time saved in training and the degree to which these materials assist craft education and training. Moreover, it will measure the interest in remote tutoring and technical assistance.

4.1.2. Valorization

Product valorization regards the increase in product value for the customer and the reduction in cost for the practitioner. The increase in product value will measure the practitioner income created by craft products enhanced with digital dimensions and new products, as well as income created by computer-aided tutoring. Reduction in production cost will measure material energy savings due to the development of efficient workflows, reduction in tutoring cost, gains from refurbishment and remanufacture, and new designs that reuse parts for a circular economy.

4.1.3. Craft Development and Revival

The development and revival of crafting and design skills regard learning from traditional techniques, reusing design inventories, using traditional techniques in contemporary products, and the reduction in experimentation costs. The objective is to revive traditional techniques and develop novel designs and fabrication possibilities. As such, craft-specific digital design and fabrication aids that help the acquisition of insight from the exploration of new designs and aid contemporary product making, as well as new materials and fabrication possibilities, are central. The pilot will measure preview realism, fabricated aids, traditional techniques utilized, and savings due to the reduction in experimentation time and cost.

4.2. Evaluation

Since the contribution of the proposed work regards the generality of the approach, the primary evaluation will address the degree to which the full range of crafts and materials is successfully applied. The assessment will evaluate the number of curricula and the degree to which digitally enhanced craft education and training are employed for the proposed approach to all RCIs.

In terms of preservation, it is proposed to evaluate how income streams are increased and diversified due to computer-aided tutoring, design, and fabrication, as well as the penetration of products in diverse markets. It is recommended to measure the crafting actions represented, the craft-specific simulators developed, the fabrication aids implemented, and the artefacts enhanced with digital dimensions.

To assess how the proposed approach motivates craft continuation and preservation, it is proposed to evaluate the response to requests for tutoring, as well as the market demands for products that blend tradition with contemporary needs from utilitarian items. Thus, the assessment measures the number of digitally enhanced education and training aids rendering learning of crafts more accessible, effective, and affordable.

The assessment of craft products valorization is proposed to be assessed by the digital dimensions of craft products through online content and certificates, the games and toys developed, as well as the products which serve personal expression, wellness, and recreation. In terms of cost reduction, it is proposed to measure the number of workflows that save materials and conserve energy, as well as the reduction in training and testing of techniques in simulation before the workshop. Moreover, it is proposed to measure the economic impact by assessing any increase in market demand, improved income opportunities, and the development of sustainable craft-based enterprises. Economic indicators regard revenue generation, employment rates, and market growth.

The sustainability of the proposed approach regards relationships and networks between research and heritage sites, cultural and creative sectors, universities, research institutions, regional/national authorities, and enterprises relevant to innovation and sustainable growth. This impact can be measured by the number of practitioners, creative industries, enterprises, and academia interested in the proposed approach. Moreover, the cultural significance can be measured by community engagement, gauged by factors such as increased awareness, participation in preservation activities, and inclusion of craft techniques in cultural events or exhibitions. In this context, it is proposed to measure the number of collaborations and partnerships due to the proposed approach, collect feedback, and compare with similar initiatives in other regions or countries. At the same time, it is important to gather feedback from users, such as trainees and practitioners. Feedback can help identify areas for improvement, ensure that the tools and resources meet the users' needs and expectations, and evaluate the knowledge exchange and dissemination efforts associated with the roadmap.

The methodology and tools proposed in this work will be integrated into the curricula of craft training institutions. Two rounds of user feedback are proposed in this work. The first regards the validation of the acquired data. The second regards the evaluation of the educational value of the interventions.

5. Conclusions

The proposed roadmap aims to outline a series of steps, strategies, and interventions necessary to safeguard and revitalize traditional crafts, including documentation, skill development, community engagement, policy advocacy, and integration of crafts into sustainable market channels. Policy recommendations for supporting craft preservation efforts providing financial incentives, fostering market access, and aiding cultural heritage policies and education curricula are provided. Compared to traditional approaches, the benefit of this work stems from the use of digital technologies in ethnographic methods to facilitate the accurate capture of crafting artefacts and manufacturing methods. Using the proposed approach, this capture assumes not only a phenomenological observation but strives to acquire a first-person perspective, that of the practitioner. Moreover, the obtained semantic representation conforms with the standards of the CH community, namely the CIDOC-CRM and EDM data models, making it extensible for future researchers to amend.

In this context, this work identifies challenges faced in the preservation of crafts and proposes preservation approaches that are generic to the type of craft and material through the provision of an abstractive and generative approach to the modeling and simulation of crafting actions, as well as ways to motivate the craft practice continuation through the diversification of practitioner income streams, digitally fabricated manufacturing aids, and resource economization.

Moreover, the importance of long-term sustainability to craft preservation is stressed. This involves considering the environmental, social, and economic dimensions of craft practices. This includes encouraging the use of sustainable materials, fostering cultural entrepreneurship, and creating markets for new craft products and services.

The need for an interdisciplinary approach to craft preservation that leverages interdisciplinary expertise, resources, and perspectives is underscored. This is due to the importance of integrating traditional craft knowledge with contemporary approaches, e.g., modern materials, technologies, and design principles to ensure the relevance and viability of crafts in contemporary contexts.

It ought to be pointed out that employing expensive equipment is not the case in this work. Most of the tasks described in this work require merely a digital camera and photogrammetric software. Indeed, commercial photogrammetric software is more user-friendly; however, open photogrammetric software is equivalently as good, albeit more tedious to operate. The most expensive component is the MoCap equipment which can be indeed judged as expensive, albeit market prices for such equipment are within the range of a typical budget of an ethnographic institution. Still, these solutions can be substituted by computer vision methods. The difference is in the accuracy of motion capture; however, this is not a critical factor for the documentation and reenactment of traditional crafts. Furthermore, the operation of this equipment is not at all dependent on expert users. First, the Mingei handbook cited in this work addresses such issues by providing detailed instructions for non-expert users on how to conduct the required data acquisition. Second, although the operation of some equipment does require some training, this is not restricted to experts, as these products are off-the-shelf and accompanied by detailed manuals and video tutorials. Third, a series of hands-on tutorials will be authored to illustrate best practices in the use of technical equipment and digitization methods. These will be accompanied by tutoring sessions that will promote the developed technologies in the context of their marketing to the community.

This work emphasizes the significance of preserving traditional crafts by recognizing their cultural heritage and treating them as economic assets and knowledge. Thus, the preservation of craft diversity and cultural identity are key for sustainable local economies and, thereby, craft preservation.

Author Contributions: Conceptualization, X.Z. and N.P. (Nikolaos Partarakis); methodology, X.Z. and N.P. (Nikolaos Partarakis); software, X.Z. and N.P. (Nikolaos Partarakis); validation, X.Z., N.P. (Nikolaos Partarakis), I.D., P.D., E.Z., A.A., C.M., V.B., N.P. (Nicolò Pratelli), C.H., M.M., P.F.S., M.K.S., L.W., S.M., G.S., A.D., C.R., D.K., D.A., G.C., M.-A.B., P.S., P.H. and J.K.; formal analysis, N.P., X.Z., E.T, E.Z., and N.P. (Nikolaos Partarakis); investigation, X.Z., N.P. (Nikolaos Partarakis), I.D., P.D., E.Z., A.A., C.M., V.B., N.P. (Nicolò Pratelli), C.H., M.M., M.K.S., L.W., P.F.S., S.M., G.S., A.D., C.R., D.K., D.A., G.C., M.-A.B., J.K., M.T., Y.M., A.Z., P.S., P.H. and E.T.; resources, X.Z., N.P. (Nikolaos Partarakis), I.D., P.D., E.Z., A.A., C.M., V.B., N.P. (Nicolò Pratelli), C.H., M.M., P.F.S., M.K.S., L.W., P.F.S., S.M., G.S., A.D., C.R., D.K., D.A., G.C., M.-A.B. and J.K.; data curation, A.D., C.R., D.K., M.-A.B., J.K., M.T., Y.M., P.S., P.H, A.Z. and E.T.; writing—original draft preparation, X.Z. and N.P. (Nikolaos Partarakis); writing—review and editing X.Z., N.P. (Nikolaos Partarakis), I.D., P.D., E.Z., A.A., C.M., V.B., N.P. (Nicolò Pratelli), C.H., M.M., P.F.S., M.K.S., L.W., P.F.S., S.M., G.S., A.D., C.R., D.K., D.A., G.C., M.-A.B., J.K., M.T., Y.M., A.Z. and E.T.; visualization, X.Z., N.P. and E.Z.; supervision, X.Z., N.P. (Nikolaos Partarakis), C.M., C.H., M.K.S., G.S., A.D., C.R., D.A., G.C. and M.-A.B.; project administration, X.Z. and N.P. (Nikolaos Partarakis); funding acquisition, X.Z., N.P. (Nikolaos Partarakis), I.D., P.D., E.Z., A.A., C.M., V.B., N.P. (Nicolò Pratelli), C.H., M.M., P.F.S., M.K.S., L.W., P.F.S., S.M., G.S., A.D., C.R., D.K., D.A., G.C., M.-A.B., J.K., M.T., Y.M., A.Z. and E.T. All authors have read and agreed to the published version of the manuscript.

Funding: This work was implemented under the project Craeft which received funding from the European Union's Horizon Europe research and innovation program under grant agreement No 101094349.

Data Availability Statement: Access to data is available upon request.

Acknowledgments: The authors thank the three anonymous reviewers for their helpful comments and their constructive criticism.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Pye, D. *The Nature and Art of Workmanship*; Cambridge University Press: Cambridge, UK, 1968.
2. Keller, M.; Keller, D. *Cognition and Tool Use*; Cambridge University Press: Cambridge, UK, 1996.
3. Donkin, L. *Crafts and Conservation: Synthesis Report for ICCROM*; ICCROM: Rome, Italy, 2001.
4. UNESCO. *Text of the Convention for the Safeguarding of the Intangible Cultural Heritage*; UNESCO: Paris, France, 2003.
5. Heritage Crafts. *Issues Affecting the Viability of Heritage Crafts Research Report*; Heritage Chairs and Officials of Australia and New Zealand; Heritage Trades and Professional Training Project; Heritage Crafts: Rugeley, UK, 2022.
6. Townsend, K.; Niedderer, K. Crafting health, well-being and happiness. *Craft Res.* **2020**, *11*, 3–8. [CrossRef]
7. Jocelyne, E. *Methodological Guide to the Collection of Data on Crafts*; Technical Report; UNESCO: Paris, France, 1990.
8. CARLI Digital Collections Users' Group. Guidelines for the Creation of Digital Collections, Consortium of Academic and Research Libraries at the University of Illinois. Available online: https://mid-coast.com/Downloads/CARLI.pdf (accessed on 23 February 2022).
9. Corns, A. Guidelines & Case Studies. 2013. Available online: http://3dicons-project.eu/guidelines-and-case-studies/guidelines (accessed on 23 February 2022).
10. Rourk, W. 3D Cultural Heritage Informatics: Applications to 3D Data Curation. *3D/VR Acad. Libr. Emerg. Pract. Trends* **2019**, *3*, 24–38.
11. Drake, K.; Justrell, B.; Tammaro, A.; WP6 Secretariat. *Good Practice Handbook*; Minerva: Copenhagen, Denmark, 2003.

12. Pitzalis, D.; Kaminski, J.; Niccolucci, F. 3D-COFORM: Making 3D documentation an everyday choice for the cultural heritage sector. *Virtual Archaeol. Rev.* **2011**, *2*, 145–146. [CrossRef]
13. Dellepiane, M.; Callieri, M.; Corsini, M.; Scopigno, R. Using digital 3D models for study and restoration of cultural heritage artifacts. In *Digital Imaging for Cultural Heritage Preservation: Analysis, Restoration, and Reconstruction of Ancient Artworks*; Consiglio Nazionale delle Ricerche: Rome, Italy, 2011; pp. 39–70.
14. Dellepiane, M.; Venturi, A.; Scopigno, R. Image Guided Reconstruction of Un-sampled Data: A Filling Technique for Cultural Heritage Models. *Int. J. Comput. Vis.* **2011**, *94*, 2–11. [CrossRef]
15. Dellepiane, M.; Benedetti, L.; Scopigno, R. Removing shadows for color projection using sun position estimation. In Proceedings of the 11th International Conference on Virtual Reality, Archaeology and Cultural Heritage, Paris, France, 21–24 September 2010; pp. 55–62.
16. Pustovrh, T.; Mali, F. (Bio) ethicists and (Bio) ethical Expertise in National Ethical Advisory Bodies: Roles, Functions and Perceptions. *Prolegomena Časopis Filoz.* **2015**, *14*, 47–69.
17. Gabriele, G.; Sara, G.; Laura, M. Image pre-processing for optimizing automated photogrammetry performances. *Ann. Photogramm. Remote Sens. Spat. Inf. Sci.* **2014**, *2*, 145–152.
18. Niccolucci, F.; Fernie, K.; D'Andrea, A. 3D-ICONS: European project providing 3D models and related digital content to Europeana. In *3D-ICONS: European Project Providing 3D Models and Related Digital Content to Europeana 2012*; Firenze University Press: Florence, Italy, 2012; pp. 51–56.
19. D'Andrea, A.; Niccolucci, F.; Bassett, S.; Fernie, K. 3D-ICONS: World Heritage sites for Europeana: Making complex 3D models available to everyone. In Proceedings of the IEEE International Conference on Virtual Systems and Multimedia, Milan, Italy, 2–5 September 2012; pp. 517–520.
20. Niccolucci, F.; Felicetti, A.; Amico, N.; D' Andrea, A. Quality control in the production of 3D documentation of monuments. In Proceedings of the Built Heritage 2013 Monitoring Conservation Management, Milan, Italy, 18–20 November 2013; pp. 864–873.
21. Fernandez-Palacios, B.; Remondino, F.; Stefani, C.; Lombardo, J.; De Luca, L. Web visualization of complex reality-based 3D models with NUBES. In Proceedings of the IEEE Digital Heritage International Congress, Marseille, France, 28 October–1 November 2013; Volume 1, pp. 701–704.
22. Remondino, F.; El-Hakim, S. Image-based 3D modelling: A review. *Photogramm. Rec.* **2006**, *21*, 269–291. [CrossRef]
23. Li, Z.; Yeh, Y.; Chandraker, M. Through the looking glass: Neural 3D reconstruction of transparent shapes. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, Seattle, WA, USA, 13–19 June 2020; pp. 1262–1271.
24. Kahle, P.; Colutto, S.; Hackl, G.; Mühlberger, G. Transkribus-a service platform for transcription, recognition and retrieval of historical documents. In Proceedings of the IAPR International Conference on Document Analysis and Recognition, Kyoto, Japan, 9–15 November 2017; Volume 4, pp. 19–24.
25. Sánchez, J.; Mühlberger, G.; Gatos, B.; Schofield, P.; Depuydt, K.; Davis, R.; Vidal, E.; Does, J. TranScriptorium: A European project on handwritten text recognition. In Proceedings of the ACM Symposium on Document Engineering, Florence, Italy, 10–13 September 2013; pp. 227–228.
26. Alborno, P.; Piana, S.; Mancini, M.; Niewiadomski, R.; Volpe, G.; Camurri, A. Analysis of intrapersonal synchronization in full-body movements displaying different expressive qualities. In Proceedings of the International Working Conference on Advanced Visual Interfaces, Bari, Italy, 7–10 June 2016; pp. 136–143.
27. Camurri, A.; Volpe, G.; Piana, S.; Mancini, M.; Niewiadomski, R.; Ferrari, N.; Canepa, C. The dancer in the eye: Towards a multi-layered computational framework of qualities in movement. In Proceedings of the International Symposium on Movement and Computing, Thessaloniki, Greece, 5–6 July 2016; pp. 1–7.
28. Piana, S.; Alborno, P.; Niewiadomski, R.; Mancini, M.; Volpe, G.; Camurri, A. Movement fluidity analysis based on performance and perception. In Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems, San Jose, CA, USA, 7–12 May 2016; pp. 1629–1636.
29. De Berardinis, J.; Meroño-Peñuela, A.; Poltronieri, A.; Presutti, V. The Music Annotation Pattern. In Proceedings of the Semantic Web–ISWC International Semantic Web Conference: Workshop on Ontology Design and Patterns, Hangzhou, China, 23–27 October 2022.
30. Carriero, V.; Ciroku, F.; De Berardinis, J.; Pandiani, D.; Meroño-Peñuela, A.; Poltronieri, A.; Presutti, V. Semantic integration of MIR datasets with the polifonia ontology network. In Proceedings of the International Society for Music Information Retrieval Conference, Online. 7–12 November 2021.
31. Lisena, P.; Meroño-Peñuela, A.; Troncy, R. MIDI2vec: Learning MIDI embeddings for reliable prediction of symbolic music metadata. *Semant. Web* **2022**, *13*, 357–377. [CrossRef]
32. Petri, I.; Julien, F. Digitising the Performing Arts. Assessment Report. 2017. Available online: https://capacoa.ca/en/research/digitizing-performing-arts/ (accessed on 2 May 2022).
33. Sporleder, C. Natural language processing for cultural heritage domains. *Lang. Linguist. Compass* **2010**, *4*, 750–768. [CrossRef]
34. Benetos, E.; Dixon, S.; Duan, Z.; Ewert, S. Automatic music transcription: An overview. *IEEE Signal Process. Mag.* **2019**, *36*, 20–30. [CrossRef]
35. Syu, Y.S.; Chen, L.; Tu, Y.F. A Case Study of Digital Preservation of Motion Capture for Bā Jiā Jiāng Performance, Taiwan Religious Performing Arts. In Proceedings of the Digital Heritage, Progress in Cultural Heritage: Documentation, Preservation, and Protection, EuroMed 2018, Nicosia, Cyprus, 29 October–3 November 2018.

36. Mokhov, S.; Kaur, A.; Talwar, M.; Gudavalli, K.; Song, M.; Mudur, S. Real-time motion capture for performing arts and stage. In Proceedings of the ACM Special Interest Group on Computer Graphics and Interactive Techniques Educator's Forum, Vancouver, BC, Canada, 12–16 August 2018; pp. 1–2.
37. Manitsaris, S.; Glushkova, A.; Katsouli, E.; Manitsaris, A.; Volioti, C. Modelling gestural know-how in pottery based on state-space estimation and system dynamic simulation. *Procedia Manuf.* **2015**, *3*, 3804–3811. [CrossRef]
38. Cooke, N. Varieties of knowledge elicitation techniques. *Int. J. Hum. Comput. Stud.* **1994**, *41*, 801–849. [CrossRef]
39. Shadbolt, N.; Smart, P.; Wilson, J.; Sharples, S. Knowledge elicitation. In *Evaluation of Human Work*, 4th ed.; CRC Press: Boca Raton, FL, USA, 2015; pp. 163–200.
40. Cordingley, E. Knowledge elicitation techniques for knowledge-based systems. In *Knowledge Elicitation: Principles, Techniques and Applications*; Diaper, D., Ed.; John Wiley & Sons: Hoboken, NJ, USA, 1989.
41. Wood, N. Transmitting Craft Knowledge: Designing Interactive Media to Support Tacit Skills Learning. Ph.D. Thesis, Sheffield Hallam University, Sheffield, UK, 2017.
42. Suchman, L.A.; Trigg, R.H. Understanding practice: Video as a medium for reflection and design. In *Design at Work: Cooperative Design of Computer Systems*; CRC Press: Boca Raton, FL, USA, 1991; pp. 65–89.
43. Mauss, M. *Manuel d'Ethnographie*; Éditions Sociales: Paris, France, 1967.
44. Atkinson, P. *The Ethnographic Imagination: Textual Constructions of Reality*; Routledge: Abingdon-on-Thames, UK, 1990.
45. Vannini, P.; Vannini, A. Artisanal Ethnography: Notes on the Making of Ethnographic Craft. *Qual. Inq.* **2020**, *26*, 865–874. [CrossRef]
46. Atkinson, P. Blowing Hot: The Ethnography of Craft and the Craft of Ethnography. *Qual. Inq.* **2013**, *19*, 397–404. [CrossRef]
47. Konstantinou, K.; Anagnostopoulos, A. Interweaving contemporary art and "traditional" crafts in ethnographic research. *Art/Res. Int. A Transdiscipl. J.* **2019**, *4*, 58–82. [CrossRef]
48. Aktaş, B.M.; Mäkelä, M. Negotiation between the maker and material: Observations on material interactions in felting studio. *Int. J. Des.* **2019**, *13*, 55–67.
49. Gibson, J. *The Senses Considered as Perceptual Systems*; Houghton Mifflin: Boston, MA, USA, 1966.
50. Brett, R.; Thomson, D.; Dainty, A. Exploring craft in construction with short-term ethnography: Reflections on a researcher's prior insight. *Constr. Manag. Econ.* **2022**, *40*, 359–373. [CrossRef]
51. Posselt, E. *The Preparation of Jacquard Cards and Practical Hints to Learners of Jacquard Designing*; Textile Department, Pennsylvania Museum and School of Industrial Art: Philadelphia, PA, USA, 1893.
52. Schmid, E. *Beginning Glassblowing*; Glass Mountain Press: Bellingham, WA, USA, 1998.
53. Tanney, J.; Ryle, G. The Thinking of Thoughts: What is 'Le Penseur' Doing? In *Collected Essays 1929–1968: Collected Papers*; Routledge: Abingdon-on-Thames, UK, 2009; Volume 2.
54. Cozzani, G.; Pozzi, F.; Dagnino, F.; Katos, A.; Katsouli, E. Innovative technologies for intangible cultural heritage education and preservation: The case of i-Treasures. *Pers. Ubiquitous Comput.* **2017**, *21*, 253–265. [CrossRef]
55. Zabulis, X.; Partarakis, N.; Meghini, C.; Dubois, A.; Manitsaris, S.; Hauser, H.; Magnenat Thalmann, N.; Ringas, C.; Panesse, L.; Cadi, N.; et al. A Representation Protocol for Traditional Crafts. *Heritage* **2023**, *5*, 716–741. [CrossRef]
56. Fuster, J. Upper processing stages of the perception–action cycle. *Trends Cogn. Sci.* **2004**, *8*, 143–145. [CrossRef]
57. Greenwood, J. The cognitive revolution. In *A Conceptual History of Psychology: Exploring the Tangled Web*; Cambridge University Press: Cambridge, UK, 2015; pp. 454–494. [CrossRef]
58. Atkinson, T.; Claxton, G. *The Intuitive Practitioner: On the Value of Not Always Knowing What One Is Doing*; Open University Press: Maidenhead, UK, 2000.
59. Gustafson, P. (Ed.) *Craft Perception and Practice: A Canadian Discourse*; Ronsdale Press: Vancouver, BC, Canada, 2002.
60. Ericsson, K.; Charness, N.; Feltovich, P.; Hoffman, R. (Eds.) *The Cambridge Handbook of Expertise and Expert Performance*; Cambridge University Press: Cambridge, UK, 2006. [CrossRef]
61. Fodor, J. *The Modularity of Mind*; MIT Press: Cambridge, MA, USA, 1983.
62. Kirkland, P.; Di Caterina, G.; Soraghan, J.; Matich, G. Perception Understanding Action: Adding Understanding to the Perception Action Cycle with Spiking Segmentation. *Front. Neurorobot.* **2020**, *14*, 568319. [CrossRef]
63. Cutsuridis, V.; Taylor, J. A Cognitive Control Architecture for the Perception–Action Cycle in Robots and Agents. *Cogn. Comput.* **2013**, *5*, 383–395. [CrossRef]
64. Masuta, H.; Motoyoshi, T.; Sawai, K.; Koyanagi, K.; Oshima, T. Perception and action cycle for cognitive robotics. In Proceedings of the International Symposium on Micro-NanoMechatronics and Human Science, Nagoya, Japan, 3–6 December 2017; pp. 1–7.
65. Shillito, A. *Digital Crafts: Industrial Technologies for Applied Artists and Designer Makers*; Bloomsbury Publishing: London, UK, 2019.
66. Bhavikatti, S. *Finite Element Analysis*; New Age International: Dhaka, Bangladesh, 2005.
67. Woodwork Simulator. Available online: https://irregularcorp.itch.io/woodwork-simulator-prototype (accessed on 21 March 2023).
68. Grow, A.; Dickinson, M.; Pagnutti, J.; Wardrip-Fruin, N.; Mateas, M. Crafting in games. *Digit. Humanit. Q.* **2017**, *11*. Available online: https://www.proquest.com/scholarly-journals/crafting-games/docview/2555194299/se-2 (accessed on 11 July 2023).
69. Almevik, G.; Jarefjäll, P.; Samuelsson, O. Tacit record: Augmented documentation methods to access traditional blacksmith skills. In Proceedings of the Design & Digital Heritage Conference, Marseille, France, 28 October–1 November 2013.

70. Chaffin, D. Human motion simulation for vehicle and workplace design. *Hum. Factors Ergon. Manuf. Serv. Ind.* **2007**, *17*, 475–484. [CrossRef]
71. Osterlund, J.; Lawrence, B. Virtual reality: Avatars in human spaceflight training. *Acta Astronaut.* **2012**, *71*, 139–150. [CrossRef]
72. Brown, C.; Hicks, J.; Rinaudo, C.; Burch, R. The use of augmented reality and virtual reality in ergonomic applications for education, aviation, and maintenance. Ergonomics in Design. *Ergon. Des.* **2021**. [CrossRef]
73. Doolani, S.; Owens, L.; Wessels, C.; Makedon, F. vIS: An immersive virtual storytelling system for vocational training. *Appl. Sci.* **2020**, *10*, 8143. [CrossRef]
74. Avgerinakis, K.; Meditskos, G.; Derdaele, J.; Mille, S.; Shekhawat, Y.; Fraguada, L.; Lopez, E.; Wuyts, J.; Tellios, A.; Riegas, S.; et al. V4design for enhancing architecture and video game creation. In Proceedings of the IEEE International Symposium on Mixed and Augmented Reality, Munich, Germany, 16–20 October 2018; pp. 305–309.
75. Symeonidis, S.; Meditskos, G.; Vrochidis, S.; Avgerinakis, K.; Derdaele, J.; Vergauwen, M.; Bassier, M.; Fraguada, L.; Vogler, V.; Shekhawat, Y.; et al. V4Design: Intelligent Analysis and Integration of Multimedia Content for Creative Industries. *IEEE Syst. J.* **2022**, *17*, 2570–2573. [CrossRef]
76. Léon, A.; Gaitán, M.; Sebastián, J.; Pagán, E.; Insa, I. SILKNOW. Designing a thesaurus about historical silk for small and medium-sized textile museums. In *Science and Digital Technology for Cultural Heritage—Interdisciplinary Approach to Diagnosis, Vulnerability, Risk Assessment and Graphic Information Models*; CRC Press: Boca Raton, FL, USA, 2019; pp. 187–190.
77. Portalés, C.; Sevilla, J.; Pérez, M.; León, A. A Proposal to Model Ancient Silk Weaving Techniques and Extracting Information from Digital Imagery-Ongoing Results of the SILKNOW Project. In Proceedings of the International Conference on Computational Science, Faro, Portugal, 12–14 June 2019; Volume 5, pp. 733–740.
78. Pagán, E.; Salvatella, M.; Pitarch, M.D.; Muñoz, A.; Toledo, M.; Ruiz, J.; Vitella, M.; Lo Cicero, G.; Rottensteiner, F.; Clermont, D.; et al. From Silk to Digital Technologies: A Gateway to New Opportunities for Creative Industries, Traditional Crafts and Designers. The SILKNOW Case. *Sustainability* **2020**, *12*, 8279. [CrossRef]
79. Rosado-García, M.; Kubus, R.; Argüelles-Bustillo, R.; García-García, M. A new European Bauhaus for a culture of transversality and sustainability. *Sustainability* **2021**, *13*, 11844. [CrossRef]
80. Sadowski, K. Implementation of the New European Bauhaus Principles as a Context for Teaching Sustainable Architecture. *Sustainability* **2021**, *13*, 10715. [CrossRef]
81. Bason, C.; Conway, R.; Hill, D.; Mazzucato, M. A New Bauhaus for a Green Deal. 2020. Available online: https://www.ucl.ac.uk/bartlett/public-purpose/sites/public-purpose/files/new_bauhaus_cb_rc_dh_mm_0.pdf (accessed on 20 March 2021).
82. Torchia, D.; Fresta, J.; Corazza, L.; Certomà, C. New European Bauhaus for a Circular Economy and Waste Management: The Lived Experience of a Community Container Garden at the University of Turin. *Sustainability* **2023**, *15*, 914. [CrossRef]
83. Pujol, L.; Roussou, M.; Poulou, S.; Balet, O.; Vayanou, M.; Ioannidis, Y. Personalizing interactive digital storytelling in archaeological museums: The CHESS project. In Proceeding of the 40th Conference of Computer Applications and Quantitative Methods in Archaeology, Southampton, UK, 22–26 March 2012; pp. 93–100.
84. Balet, O.; Koleva, B.; Grubert, J.; Yi, K.; Gunia, M.; Katsis, A.; Castet, J. Authoring and living next-generation location-based experiences. *arXiv* **2017**, arXiv:1709.01293.
85. Fassold, H.; Karakottas, A.; Tsatsou, D.; Zarpalas, D.; Takacs, B.; Fuhrhop, C.; Manfredi, A.; Patz, N.; Tonoli, S.; Dulskaia, I. The Hyper360 toolset for enriched 360. In Proceeding of the IEEE International Conference on Multimedia & Expo Workshops, Virtual Conference, 6–10 July 2020; pp. 1–4.
86. Karlatos, D.; Agrafiotis, P.; Balogh, T.; Bruno, F.; Castro, F.; Petriaggi, B.; Demesticha, S.; Doulamis, A.; Drap, P.; Georgopoulos, A.; et al. Project iMARECULTURE: Advanced VR, iMmersive serious games and augmented REality as tools to raise awareness and access to European underwater CULTURal heritagE. In Proceedings of the Digital Heritage, Progress in Cultural Heritage: Documentation, Preservation, and Protection: International Conference, Nicosia, Cyprus, 31 October–5 November 2016; pp. 805–813.
87. Katifori, A.; Roussou, M.; Perry, S.; Drettakis, G.; Vizcay, S.; Philip, J. The EMOTIVE Project-Emotive Virtual Cultural Experiences through Personalized Storytelling. In Proceedings of the Workshop on Cultural Informatics Research and Applications, Nicosia, Cyprus, 3 November 2018; pp. 11–20. Available online: https://ceur-ws.org/Vol-2235/paper2.pdf (accessed on 11 July 2023).
88. Sykora, M.; Jackson, T.; O'Brien, A.; Elayan, S. *Emotive Ontology: Extracting Fine-Grained Emotions from Terse, Informal Messages*; Department of Information Science, Loughborough University: Loughborough, UK, 2013.
89. Da Milano, C.; Falchetti, E.; Migone, P.; Nisi, V. Digital storytelling, cultural heritage, and social inclusion: The MEMEX project. In *Digital Approaches to Inclusion and Participation in Cultural Heritage*; Routledge: Abingdon-on-Thames, UK, 2023; pp. 8–26.
90. Friston, S.; Congdon, B.; Swapp, D.; Izzouzi, L.; Brandstätter, K.; Archer, D.; Olkkonen, O.; Thiel, F.; Steed, A. Ubiq: A system to build flexible social virtual reality experiences. In Proceedings of the ACM Symposium on Virtual Reality Software and Technology, Osaka, Japan, 8–10 December 2021; pp. 1–11.
91. Ritschel, H.; Kiderle, T.; André, E. Implementing Parallel and Independent Movements for a Social Robot's Affective Expressions. In Proceedings of the International Conference on Affective Computing and Intelligent Interaction Workshops and Demos, Nara, Japan, 28 September–1 October 2021; pp. 1–4.
92. Yin, T.; Hoyet, L.; Christie, M.; Cani, M.; Pettre, J. The One-Man-Crowd: Single User Generation of Crowd Motions Using Virtual Reality. *IEEE Trans. Vis. Comput. Graph.* **2022**, *28*, 2245–2255. [CrossRef] [PubMed]

93. Hadjicosti, I.; Nikolaou, P.; Asimenou, M. CH Sustainable Management Guidelines 1st POLICY BRIEF, EU Funded Project ReInHerit—Redefining the Future of Cultural Heritage, through a Disruptive Model of Sustainability GA. No. 101004545. 2022. Available online: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5e9abe79c&appId=PPGMS (accessed on 23 March 2023).
94. Tykhonova, O. Collection of Best Practices and Learnings, EU Funded Project DOORS—Digital Incubator for Museums, GA. NO. 101036071. 2022. Available online: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5eba0fdde&appId=PPGMS (accessed on 23 March 2023).
95. Janus, A.; Tarkowski, A.; Strycharz, J.; Drabczyk, M.; Centrum, C. Policy Report on Value Chains of CHIs in Digital Single Market. EU Funded Project inDICEs—Measuring the Impact of Digital CulturE. GA No: 870792. 2021. Available online: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5d8e8b1c5&appId=PPGMS (accessed on 23 March 2023).
96. Crociata, A. Policy Recommendations Statistical Analyses and Mapping of CCIs. EU Funded Project DISCE—Developing Inclusive and Sustainable Creative Economies. GA No: 822314. 2022. Available online: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5ecfa9ea2&appId=PPGMS (accessed on 23 March 2023).
97. Dent, T.; Comunian, R.; Kim, S. Policy Recommendations for Promoting Creative Workforce and Creative HE in Europe. EU Funded Project DISCE—Developing Inclusive and Sustainable Creative Economies. GA No: 822314. 2022. Available online: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5ee371d64&appId=PPGMS (accessed on 23 March 2023).
98. Davidson, D. *Essays on Actions and Events*; Oxford University Press: Oxford, UK, 2003.
99. MatWeb, Your Source for Materials Information. Available online: https://www.matweb.com/ (accessed on 23 May 2023).
100. Lewis, C. *Mind and the World-Order: Outline of a Theory of Knowledge*; Charles Scribner's Sons: New York, NY, USA, 1929; Volume 121.
101. Dennett, D. Quining qualia. In *Consciousness in Contemporary Science*; Oxford University Press: New York, NY, USA, 1988; pp. 42–77.
102. Doerr, M. The CIDOC conceptual reference module: An ontological approach to semantic interoperability of metadata. *AI Mag.* **2003**, *24*, 75.
103. Baca, M.; Gill, M. Encoding multilingual knowledge systems in the digital age: The Getty vocabularies. *Knowl. Organ.* **2015**, *42*, 232–243. [CrossRef]
104. Aitchison, J. *UNESCO Thesaurus: A Structured List of Descriptors for Indexing and Retrieving Literature in the Fields of Education, Science, Social Science, Culture and Communication*; UNESCO: Paris, France, 1977.
105. Mo, K.; Guerrero, P.; Yi, L.; Su, H.; Wonka, P.; Mitra, N.; Guibas, L. Structurenet: Hierarchical graph networks for 3D shape generation. *ACM Trans. Graph.* **2019**, *38*, 1–19. [CrossRef]
106. Mezghanni, M.; Boulkenafed, M.; Lieutier, A.; Ovsjanikov, M. Physically-aware generative network for 3D shape modeling. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, Nashville, TN, USA, 20–25 June 2021; pp. 9330–9341.
107. Deng, Y.; Yang, J.; Tong, X. Deformed implicit field: Modeling 3D shapes with learned dense correspondence. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, Nashville, TN, USA, 20–25 June 2021; pp. 10286–10296.
108. Zhang, Y.; Chen, W.; Ling, H.; Gao, J.; Zhang, Y.; Torralba, A.; Fidler, S. Image GANs Meet Differentiable Rendering for Inverse Graphics and Interpretable 3D Neural Rendering. In Proceedings of the International Conference on Learning Representations, Addis Ababa, Ethiopia, 26–30 April 2020. Available online: https://openreview.net/forum?id=yWkP7JuHX1 (accessed on 23 May 2023).
109. Ingold, T. From the transmission of representations to the education of attention. In *The Debated Mind: Evolutionary Psychology versus Ethnography*; Whitehouse, H., Ed.; Berg Publishers: Oxford, UK, 2001; pp. 113–153.
110. Marr, D. *Vision: A Computational Investigation of Human Representation & Processing of Visual Information*; W. H. Freeman and Company: New York, NY, USA, 1982.
111. Vilfayeau, J.; Crépin, D.; Boussu, F.; Soulat, D.; Boisse, F. Numerical modelling of the weaving process for textile composite. In *Key Engineering Materials*; Trans Tech Publications Ltd.: Bäch, Switzerland, 2013; Volume 554, pp. 472–477.
112. Behera, B.; Hari, P.; Labanieh, A. Modelling the structure of woven fabrics. In *Woven Textiles*; Woodhead Publishing: Sawston, UK, 2020; pp. 291–328.
113. Wang, Z.; Zhang, Y.; Bernard, A. A constructive solid geometry-based generative design method for additive manufacturing. *Addit. Manuf.* **2021**, *41*, 101952. [CrossRef]
114. Nesme, M.; Kry, P.; Jeřábková, L.; Faure, F. Preserving topology and elasticity for embedded deformable models. In Proceedings of the ACM Special Interest Group on Computer Graphics and Interactive Techniques Papers, New Orleans, LO, USA, 3–7 August 2009; pp. 1–9.
115. Field, H.; Long, J.; Field, H.; Long, J. *Simple Machines. Introduction to Agricultural Engineering Technology: A Problem-Solving Approach*; Springer: Berlin/Heidelberg, Germany, 2018; pp. 43–57.
116. Chen, H.; Tang, H.; Shi, H.; Peng, W.; Sebe, N.; Zhao, G. Intrinsic-extrinsic preserved GANs for unsupervised 3D pose transfer. In Proceedings of the IEEE/CVF International Conference on Computer Vision, Montreal, BC, Canada, 11–17 October 2021; pp. 8630–8639.

117. Yoon, J.; Liu, L.; Golyanik, V.; Sarkar, K.; Park, H.; Theobalt, C. Pose-guided human animation from a single image in the wild. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, Nashville, TN, USA, 20–25 June 2021; pp. 15039–15048.
118. Petrovich, M.; Black, M.; Varol, G. Action-conditioned 3D human motion synthesis with transformer VAE. In Proceedings of the IEEE/CVF International Conference on Computer Vision, Montreal, BC, Canada, 11–17 October 2021; pp. 10985–10995.
119. Peng, S.; Dong, J.; Wang, Q.; Zhang, S.; Shuai, Q.; Zhou, X.; Bao, H. Animatable neural radiance fields for modeling dynamic human bodies. In Proceedings of the IEEE/CVF International Conference on Computer Vision, Montreal, BC, Canada, 11–17 October 2021; pp. 14314–14323.
120. Liu, S.; Jiang, H.; Xu, J.; Liu, S.; Wang, X. Semi-supervised 3D hand-object poses estimation with interactions in time. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, Nashville, TN, USA, 20–25 June 2021; pp. 14687–14697.
121. Chen, Y.; Tu, Y.; Kang, D.; Bao, L.; Zhang, Y.; Zhe, X.; Chen, R.; Yuan, J. Model-based 3D hand reconstruction via self-supervised learning. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, Nashville, TN, USA, 20–25 June 2021; pp. 10451–10460.
122. Cao, Z.; Radosavovic, I.; Kanazawa, A.; Malik, J. Reconstructing hand-object interactions in the wild. In Proceedings of the IEEE/CVF International Conference on Computer Vision, Montreal, BC, Canada, 11–17 October 2021; pp. 12417–12426.
123. Huang, Z.; Hu, Y.; Du, T.; Zhou, S.; Su, H.; Tenenbaum, J.; Gan, C. Plasticinelab: A soft-body manipulation benchmark with differentiable physics. In Proceedings of the International Conference on Learning Representations, Vienna, Austria, 4 May 2021.
124. Lin, X.; Huang, Z.; Li, Y.; Tenenbaum, J.; Held, D.; Gan, C. Diffskill: Skill abstraction from differentiable physics for deformable object manipulations with tools. In Proceedings of the International Conference on Learning Representations, Virtual, 25–29 April 2022.
125. Loh, P.; Burry, J.; Wagenfeld, M. Workmanship of risk: Continuous designing in digital fabrication. In Proceedings of the International Conference on Computer-Aided Architectural Design Research in Asia: Living Systems and Micro-Utopias: Towards Continuous Designing, Melbourne, VIC, Australia, 30 March–2 April 2016; pp. 651–660.
126. Proof of Attendance Protocol. Available online: https://poap.xyz/ (accessed on 21 May 2023).
127. Polanyi, M. *Personal Knowledge: Towards a Post-Critical Philosophy*; University of Chicago Press: Chicago, IL, USA, 2015.
128. California Department of Industrial Relations; The National Institute for Occupational Safety and Health Easy Ergonomics. *A Guide to Selecting Non-Powered Hand Tools*; DHHS (NIOSH) Publication; NIOSH: Cincinnati, OH, USA, 2004; Volume 164.
129. Clarke, S.; Lameras, P.; Dunwell, I.; Balet, O.; Prados, T.; Avantangelou, E. A training framework for the creation of location-based experiences using a game authoring environment. In Proceeding of the European Conference on Games Based Learning, Steinkjer, Norway, 8–9 October 2015; Volume 125.
130. Dehaene, S.; Changeux, J. Reward-dependent learning in neuronal networks for planning and decision making. *Prog. Brain Res.* **2000**, *126*, 217–229.
131. Gatys, L.; Ecker, A.; Bethge, M. Image Style Transfer Using Convolutional Neural Networks. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, Las Vegas, NV, USA, 27–30 June 2016; pp. 2414–2423.
132. Nimkulrat, N. Hands-on intellect: Integrating craft practice into design research. *Int. J. Des.* **2012**, *6*, 1–14.
133. *ISO 14001:2015*; Environmental Management Systems—Requirements with Guidance for Use. ISO/TC 207/SC 1. ISO: Geneva, Switzerland, 2015. Available online: https://www.iso.org/standard/60857.html (accessed on 28 March 2023).
134. Bijan, S. Here's What It's Like to Craft Live on Stream. 2021. Available online: https://www.theverge.com/22303070/twitch-makers-crafting-diy-woodworking-leatherworking (accessed on 28 March 2023).
135. Wikihow. Available online: https://www.wikihow.com/Main-Page (accessed on 28 March 2023).

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.