ROUTLEDGE ADVANCES IN ART AND VISUAL STUDIES

CRAFT AND DESIGN PRACTICE FROM AN EMBODIED PERSPECTIVE

Edited by

NITHIKUL NIMKULRAT AND CAMILLA GROTH

ROUTLEDGE

"This splendid collection advances our understanding of embodied cognition and experiential knowledge in craftwork and sets the pace for future theory. Its multidisciplinary cast of authors deliver unique insights into human-material interactions, skilled situated practice, and the dynamics of thinking through making – both in traditional crafts and the emerging digital and virtual realms".

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"This book shines a light on the nature and value of embodied experiences within the spheres of making and materiality. The various chapters bring ideas around becoming, feeling, wellbeing, interconnection, and relationality to the fore, which are all critical aspects of craft and design practices that seek to counter dominate modes of production and affect positive change. I would recommend this book to those who wish to establish, understand, and champion such practice".

Faith Kane, *Toi Rauwhārangi College of Creative Arts, Massey University*

Craft and Design Practice from an Embodied Perspective

This book brings together contributors from multiple disciplines, such as crafts, design, art education, cognitive philosophy, and sociology, to discuss craft and design practice from an embodied perspective.

Through theoretical overviews of embodied cognition and research-based cases that involve the researchers' making experiences, different phenomena of human-material interaction are presented, analysed, and discussed. The practical cases exemplify ways in which embodied notions show up in action. Contributors examine topics such as the embodied basis of craft activities and material manipulation, experiential knowledge and skill learning, reflection in and on action, and material dialogues. Several chapters specifically discuss the hybrid forms of analogue and digital crafting that increasingly takes place in the field of crafts and design, and the changed notions of material engagement that this entails.

The book will appeal to scholars of crafts, design, art education, anthropology, and sociology.

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Collaborative embodied knowledge through material tinkering

Stefano Parisi, Venere Ferraro, and Valentina Rognoli

Introduction

Over the past decades, emerging materials have gained prominence in design practice, driving innovation and generating added value to products and systems; they play a crucial role in improving physical performance and enhancing product language, facilitating novel dynamic experiences and unique expressive-sensorial dimensions.

Indeed, the material domain is undergoing a transformative shift, characterized by hybridization, dynamism, and interactivity, ultimately reshaping craft practices and sensorial experiences. In this context, a new class of emerging breakthrough materials defined by the umbrella definition of *interactive connected smart (ICS) materials* (Parisi et al., 2018) appears as pivotal in redefining meaningful experiences and making practices. This category encompasses a wide range of elements, including conductive materials, stimuli-responsive smart materials, embeddable sensors, actuators, and microcontrollers. As in a kind of composite arrangement, these components can be combined with inactive material substrates to form *hybrid material systems (HMS)* enabling diverse interactive and dynamic experiences by holistically tuning their material, temporal, and form dimensions (Parisi, 2021).

In this chapter, we present and discuss the embodied experience emerging from crafting HMS resulting from the hybridization of bioplastics and embedded lighting technology. For this purpose, we unfold the knowledge at the core of ICS materials and HMS. We then outline the value of the embodied experience as a result of applying a material-centred hands-on approach. This approach involves do-it-yourself (DIY) practices, material tinkering, and experimentation in a cross-disciplinary team with eclectic backgrounds from material design and crafting to interaction design and digital fabrication. Our investigation emphasizes the central role or the expressive-sensorial qualities and materials experience. We then present our experimentation in tinkering with hybrid bio-based smart objects. Finally, we reflect on the crafting experience and discuss emerging methods and approaches for design practitioners dealing with ICS Materials and HMS. The emphasis lies in collaborative practices, experiential learning, and the unique materials experience resulting from the relations between form, behaviours, material qualities, and the researchers themselves.

Theoretical background

We live in a world permeated by advanced technologies that have reshaped human experiences and interaction with the environment and artefacts (Greenfield, 2018). Novel technologies uncover new ways to engage, entertain, and inform users, and encode new

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communication and interaction languages. The rapid diffusion of emerging technologies, miniaturization, and digital fabrication has also impacted the material domain, catalysing the rise of HMS: material-based systems combining inactive materials; smart material components; and embedded sensing, computing, and actuating technologies.

Scholars from different disciplines such as design, material science, and human-computer interaction (HCI) have theorized different concepts relatable to HMS: (a) *expanded matter or x-matter*, materials enhanced with additional capacities such as tracking, sensing, responding, interacting, by integrating information technologies (Brownell, 2014); (b) *augmented materials*, materials with physical and computational properties, where electronics are embedded during the material's fabrication (Razzaque et al., 2013); (c) *computational composites,* composite materials in which at least one component has computational capabilities (Vallgårda & Redström, 2007); (d) *smart material composites*, smart materials combined to create complex interactions (Barati, 2019); (e) *hybrid materials*, compound of both organic and inorganic components, including micro components of a different nature, such as electronics (Saveleva et al., 2019; Torres et al., 2019); and (f) *smart composite material systems,* as a combination of smart materials providing sensor systems, actuating mechanisms, and control systems (Kelly et al., 2018).

The HMS anatomy emerges as a combination of diverse material layers or "building blocks" (Parisi & Ferraro, 2021) where the actuating, connecting, and sensing behaviours are provided by the presence of *ICS materials*. ICS materials is an overarching category of materials with interactive capabilities – including conductive materials, stimuli-responsive smart materials, embeddable sensors, actuators, and microcontrollers (Rognoli & Parisi, 2021a). ICS materials are defined as materials able to (a) establish a two-way exchange of information; (b) respond contextually and reversibly to external stimuli; (c) be linked to another entity or an external source; and (d) be programmable, not necessarily through software.

The *HMS* components are categorized into (a) *inactive components*, conventional passive materials such as paper, plastic, and textiles, whose dynamic behaviours are limited to conventional mechanical and chemical characteristics, such as ageing over time and performing flexibility; (b) *reactive components*, such as smart materials able to change some features like shape, colour, or light-emission in response to physical or chemical influences from the environment or the user's body, such as temperature, light, pressure, and mechanical stress, electric or magnetic field, chemical elements, and compounds; (c) *active components*, embedded sensing and actuating technologies, such as sound, touch, and proximity sensors, as well as LEDs, buzzers, or actuators, connected to external or embedded computing technologies; (d) *interconnection elements*, between components, through traditional wires or conductive materials, such as graphite, active carbon, and silver, and can be found in the shape of conductive fibres, threads, printed circuits, paints, and coating; (e) *sources of energy*, embeddable power supplies, like flexible batteries, or electricity-generating materials, such as piezoelectric ceramics and polymers. These components can be arranged in a variety of possible combinations to achieve systems with passive and/or active performances. Considering e-textiles, for example, designers combine traditional fabrics like cotton with ICS materials, such as conductive threads and LEDs. When worn, soft circuits within the fabric detect interactions and trigger LED responses. The interplay between traditional fabric and soft circuits forms a HMS, which transforms the piece of clothing into an informative, interactive design, and generates dynamic material qualities. As in a composite material arrangement, fabric and ICS materials unite to create a cohesive, interactive whole.

Beyond their functionality, designers can leverage the expressive-sensorial dimension of these materials (Rognoli, 2010) to enable sensorial references, emotions, meanings, and performances (Giaccardi & Karana, 2015; Karana et al., 2015), culminating in unique material experiences (Karana et al., 2015), such as dynamic ones. In the context of materials, the concept of dynamism manifests in different ways (Rognoli, 2015). Due to their constant change over time, materials are inherently dynamic. Examples of dynamism in conventional materials can be observed in the shrinkage and discolouration phenomena of organic materials, as well as naturally occurring reversible behaviours, such as bioluminescence of micro-organisms or moisture-induced shape-shifting of cellulose-based materials. Dynamism is even more pronounced in HMS. Indeed, HMS can change over time, interacting dynamically with users and yielding emotive, suggestive experiences. ICS materials dynamically change form and behaviour, generating new affordances and communication languages, creating unique material interfaces, and defining new interactions. They are "becoming materials" (Bergström et al., 2010), capable of multiple, repetitive, and temporally controlled expressions. From this viewpoint, they become informative and intuitive dialogical carriers of information, thanks to the hybridization of technology and materials. Blending technologies and materials with different properties, qualities, and affordances to create new dynamic experiences is one of the designer's tasks in this context.

The democratization of technologies and hybridization of the design space have enabled designers and makers to diverge from conventional production by crafting HMS themselves using ICS Materials (Coelho et al., 2009). This phenomenon is acknowledged as DIY materials (Rognoli et al., 2015). DIY materials emerge from individual or collective self-production experiences as a result of a process of experimenting and tinkering with materials. These materials include various technological blends and hybridization with interactive and smart elements, such as sensing, actuating, and computing technologies (Rognoli & Ayala-Garcia, 2021). Recent studies on the integration of electronics into bio-based materials using a DIY approach as a way to experiment with HMS using abundant, renewable, and biodegradable resources have emerged. For example, mycelium has been used to embed electronics to create breadboards (Lazaro Vasquez & Vega, 2019a), wearables (Lazaro Vasquez & Vega, 2019b), tangible interfaces with different actuators (Genç et al., 2022), and interactive artefacts (Gough et al., 2023; Weiler et al., 2019). Bacterial cellulose has been used to house LEDs for the creation of wearables (Bell et al., 2023; Ng, 2017) and encase different electronics, conductive, and smart materials for prototyping interactive devices (Nicolae et al., 2023). Bioplastics have been used to create interactive objects by embedding electronics such as LEDs (Kretzer & Mostafavi, 2020), conductive materials (Koelle et al., 2022; Lazaro Vasquez et al., 2022), and thermo-chromic dyes (Bell et al., 2022). Empowered by a DIY approach, digital technologies, and open-source tools, design researchers and practitioners can develop samples and prototypes, formalize models and methodologies, and ultimately catalyse innovation and change.

In this materials-making journey, practitioners unlock potentials and limits of the materials through material tinkering (Parisi et al., 2017; Rognoli & Parisi, 2021b), an approach rooted in HCI and craft practices that involves hands-on explorations of materials in a playful and creative manner (Bevan et al., 2015; Cermak-Sassenrath & Møllenbach, 2014; Sundström & Höök, 2010; Wilkinson & Petrich, 2014). Both the HCI and the craft communities have explored the implications of this approach's direct engagement with materials and experiential learning (Falin, 2022; Niedderer, 2007; Nimkulrat, 2012; Seitamaa-Hakkarainen et al., 2013; Vallgårda & Fernaeus, 2015). Experiential learning theory (Kolb & Fry, 1975) promotes acquisition and application of knowledge, skills, and feelings, by being involved in direct encounters with the studied phenomena rather than thinking about the encounters. The experiential learning cycle comprises applying, experiencing, reflecting, and generalizing, i.e., active experimentation, concrete experience, reflective observation, and abstract conceptualization.

The first phase of material tinkering is generally more explorative, goal-free, and discovery-oriented, often revealing unpredictable outcomes. It encompasses embodied explorations that foster experiential knowledge and creativity. In this phase, designers discover the performances and expressions of materials and practise their experiential sensibility and vocabulary. In contrast, the second phase is characterized by a more structured investigation to achieve an intended outcome or answer a specific research question. It encompasses practical inquiries that aid iterative material improvement and understanding of material-process-form relationships, thereby enhancing knowledge creation.

Experimenting with materials at any phase of tinkering allows for a unique embodied experience. While manipulating and crafting with materials, designers are actively engaged in a continuous embodied conversation with them (Schön & Bennett, 1996), generating new knowledge, meanings, and experiences. Indeed, tinkering enhances materials' agency, elevating the materials to a collaborator (Rosner, 2012), a co-performer (Robbins et al., 2016), and an equal partner (Barati & Karana, 2019). In this process, materials play an active role by suggesting ways of interaction and manipulation, while the designer must be open to listening and interpreting the feedback from the manipulated material.

In particular, tinkering with ICS materials for HMS crafting is a conversation among several actors: the designers, the inactive materials and their crafting techniques, the interactive elements and their programming, and the component organizations in the system forming process. In this process, the designers engage in dynamic, interactive, and hybrid types of embodied material experiences.

Material tinkering: applying and experiencing

In this section, we describe a case study of embodied knowledge and materials experience emerging from collaborative crafting experimentation of HMS with the use of ICS materials and bioplastics. It aimed at the creation of bio-based smart objects with interactive behaviours.

The experimentation involved a mixed team of four design researchers with expertise on material design, product design, digital fabrication, and HCI. It was conducted in two distinctive phases of material tinkering over four months, between January and April 2019. The experimentation was part of the first author's PhD research project under the supervision of the third author (Parisi, 2021). Centring their focus on material design, mainly dealing with bio-based materials and DIY approaches, they collaborated with two other researchers who contribute to the experimentation with their digital fabrication and HCI expertise.

Explorative and systematic material tinkering

The research team freely approached explorative material tinkering, aiming to understand the potentials and limitations in variations, processability, forming, and augmentation of different organic DIY materials. These materials include mycelium-based materials,

Figure 14.1 Samples from the first experimentation. From left: mycelium-based, animal gelatine-based and agar-agar-based bioplastics, damar gum and rosin, and fruit leather samples. Photographs by Stefano Parisi.

starch-based biopolymers, animal gelatine-based biopolymers, vegetal gelatine-based biopolymers (i.e., agar-agar based), natural resins (i.e., damar gum and rosin), pectin-based biopolymers (i.e., fruit leather), and casein-based biopolymers (Figure 14.1). Inspired by the recipes from online open publications (Pistofidou & Dunne, 2018; Ribul, 2014; Viladrich, 2014), we experimented with different ingredients and recipes by manipulating ratios, processes, and moulding shapes. We attached a label with an alpha-numerical code to each sample we generated. To keep track of the processes and practices, we documented the codes associated with the samples in a notebook. This allowed us to link the variables in the processes to the material qualities of the final samples, as experienced through sensory exploration. At this stage, tactile, visual, and olfactory exploration was a way of experiencing the materials through our senses. From the first experiments, we produced about a hundred material samples with different characteristics.

Aiming to select a single material for further experimentation in a more systematic way, we evaluated the material samples according to different criteria, such as stability, variations in visual and tactual qualities (e.g., translucency and textures), embedment of smart components (both technology and smart materials), scalability, time of preparation, economic cost, and environmental impact. The criteria were mainly related to the main objective of the following experimentation stage, i.e., to reproduce a variety of qualities and to obtain stabilized samples to integrate technologies. Finally, we identified the animal gelatine-based bioplastic as the most promising material for the following experimentation.

After we selected the material – i.e., animal gelatine-based bioplastic – we performed a systematic material tinkering to produce samples in the same shape as a fixed variable but differing in material variables. Using this approach, the shape was not the focus of the exploration and would not interfere with the perception of the material qualities in the different samples. Starting from the original recipe, we explored different variables by altering the ratio of ingredients in the recipe and some procedures in the making process, and by integrating dynamic behaviours. We have produced about 40 samples embedding different qualities. The following sections describe details of their material qualities, forming techniques and integration of interactive components.

Material qualities

The selected recipe consists of three ingredients: animal gelatine, water, and glycerine. We found that we could achieve different material qualities by modifying the ratio of these ingredients. For example, increasing the amount of glycerine would make the sample

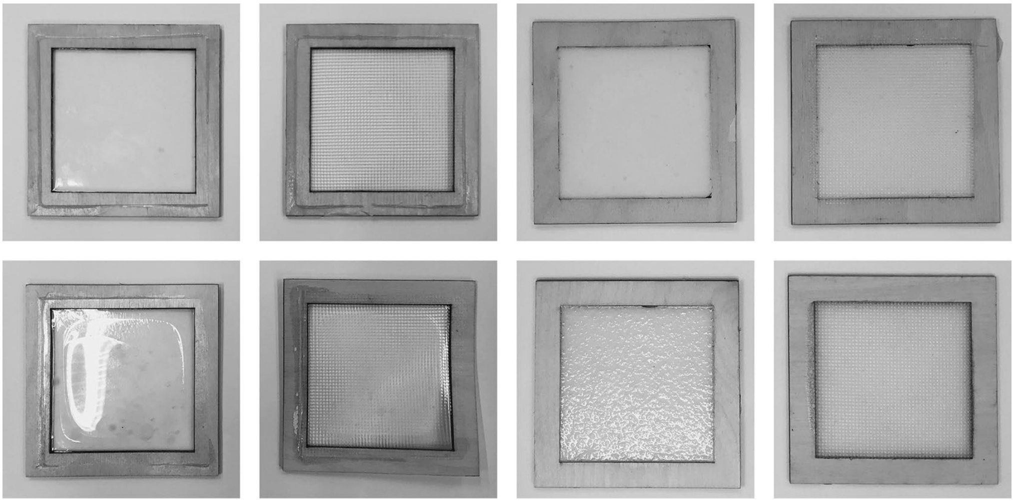

Figure 14.2 Samples combining the three contrasting qualities: flexible/stiff, transparent/opaque, and textured/smooth. Clockwise from top left: flexible, transparent, smooth; flexible, transparent, textured; flexible, opaque, smooth; flexible, opaque, textured; stiff, transparent, smooth; stiff, transparent, textured; stiff, opaque, smooth; stiff, opaque, texture. Photographs by Stefano Parisi.

more flexible, or reducing the amount of water and increasing the amount of gelatine would give the sample an opaque appearance. This recipe was also the most reliable in terms of results and reproducibility, the easiest to process, and the fastest to stabilize. Even though many qualities, e.g., scent, were identified, we chose to focus our systematic tinkering on the three most evident visual and tactile qualities, including flexible/stiff, transparent/opaque, and textured/ smooth. By matching these dimensions on a matrix, we created eight samples, each representing a specific combination of the systematically manipulated qualities (Figure 14.2).

Forming techniques

The making process corresponded to the process of cooking bioplastics: melting the ingredients together, then pouring the material and letting it dry on a surface. The material can be poured onto a flat surface to produce a thin layer of material or into three-dimensional moulds to obtain a solid with a three-dimensional volume, e.g., spheres. For our experiment, we wanted to achieve samples with homogenous thickness in all their volume, so once they were consistently dry, they could be compared with one another. For this reason, we decided to produce thin layers of bioplastic by pouring it into and letting it dry in a laser-cut wooden frame positioned on a non-sticky plastic surface. This plastic surface was laser-engraved to create a texture transferrable onto the material sample. After a few days, the material was stable and dry, allowing the plastic surface to be easily removed while the sample remained attached to the wooden frame (Figure 14.3). This rigid frame, therefore, served several purposes, including (a) shaping the sample during the moulding process, (b) preventing shrinkage and deformation of the material, (c) making the samples easy to handle and collect, (d) protecting the materials during transport and manipulation, (e) embedding electronic components, and (f) embossing the item's code.

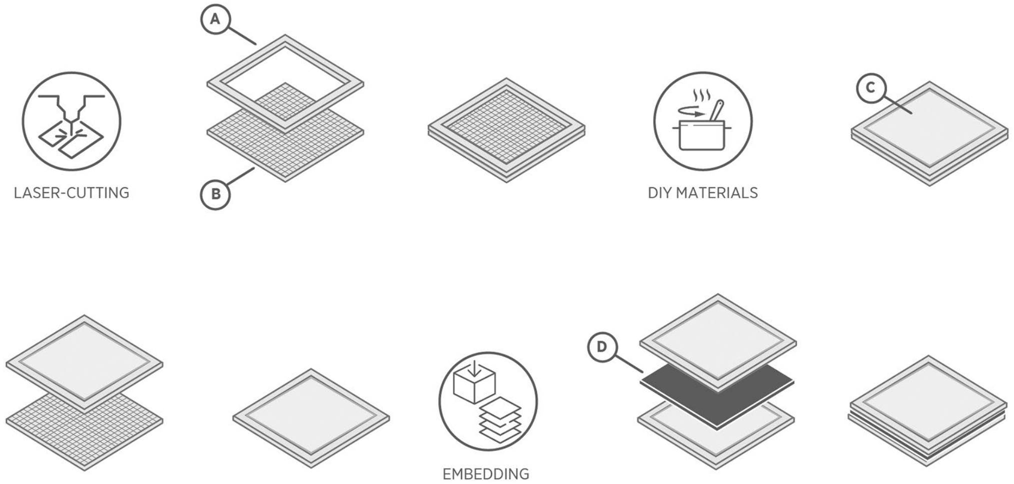

Figure 14.3 A schematic representation of the making of a sample. First, a wooden frame combined with a textured plastic surface is used to give shape and texture to the bioplastic sample. Then, the obtained sample is used to contain technologies, e.g., LEDs, batteries, and microcontroller. (A) Squared wooden frame; (B) textured or smooth plastic surface; (C) bioplastic; (D) technologies. Illustration by Stefano Parisi.

Integration of dynamic behaviours

We focused part of the experimentation on the identification of techniques to augment the material by adding dynamic behaviours through the integration of technologies into the material. In this respect, we decided to use the moulding frame as a platform for embedding the technologies. Inspired by a unique sensorial quality of the bioplastic – its nuances of translucency degrees – we chose to focus on light-emitting behaviour. To enact this behaviour, we considered two approaches: first, pouring light-emitting diodes (LED) directly into the bioplastic and using the frame to position the LEDs; and second, overlaying two samples and using the space between them to integrate the LEDs (Figure 14.4). We used the frame to hide interconnection, batteries, Arduino, and sensors on the inside. Potentially, we could activate the behaviour by a motion sensor controlling the LEDs. This would be implemented using an Arduino Mini board with a motion sensor to detect the samples being picked up and put down. This would result in an output of LED lights by switching the actuators on and off.

Observations: reflecting and generalizing

Reflecting on the ideation and making of these samples and the experience of the designer has led to a discussion about processes, functionalities, affordances, expressions, meanings, and ultimately the novel materials experiences expressed by this hybrid crafting practice. In particular, the intertwined relations between material making, forming, and technology integration into a prototype has revealed constraints and opportunities for the performativity and expression of HMS. This dialogue has grounded and cultivated collaborative embodied knowledge.

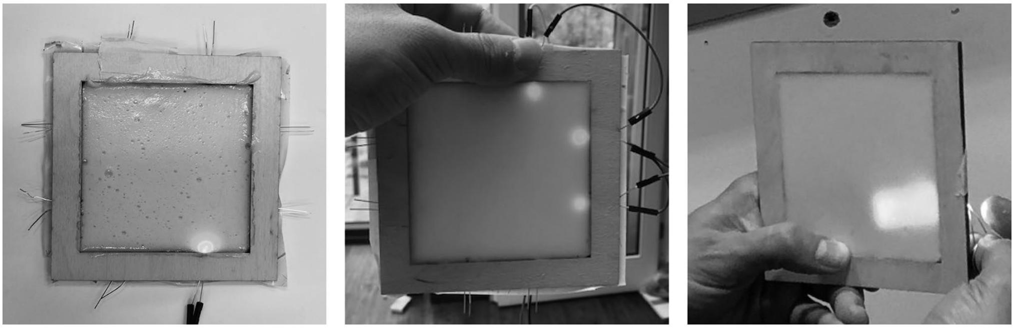

Figure 14.4 Experimentation with material augmentation to produce light-emitting samples, using two approaches. First, LEDs are placed in the back of the frame and integrated into bioplastic during the pouring and drying process (left and middle) and second, the light source is placed on the back of the sample for a more diffused lighting and covered by another sample layered on the back (right). Photographs by Stefano Parisi.

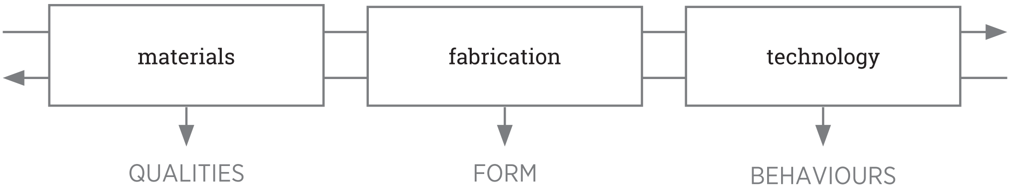

Figure 14.5 Relations between qualities, forms, and behaviours in HMS crafting. Illustration by Stefano Parisi.

Relations between material qualities, form, and behaviours in crafting ICS materials

The prototyping method includes the making of DIY bioplastics, programming and integration of smart components, and digital fabrication (e.g., laser cutting of the wooden frame and engraving of plastic surface). From the analysis of the results generated by the experimentation, we can identify three main dimensions of HMS: (a) qualities, characterized by material recipes; (b) form, characterized by fabrication techniques; and (c) behaviours, characterized by the digital technology (Figure 14.5). Therefore, the design processes required to deliver HMS are simultaneously material making, forming, and technology programming, resulting in a physical sample; these three dimensions are fundamentally intertwined, as materials and technology can inform each other. As the experiments evidence, the outcome is often dependent on the craft process, which thus becomes an essential element of material augmentation.

In the observed case study, materials are engaged in different relations with the technology. They can be elements that support or contain electronics and smart components. As sensory interfaces, materials contribute to HMS by providing their intrinsic qualities, e.g., optical and tactile, and characteristics, e.g., mechanical and environmental. This is the case of transparency/opaqueness, flexibility/rigidity, and texture/smoothness explored in the samples. The material translucency enhances the light diffusion of LEDs. The material inherently emphasizes or augments the technology actuation due to one of its qualities.

At the same time, we can transform and design the material to enable or characterize the behaviour. In the experimentations, by combining DIY bioplastics as an easily customizable material and digital fabrication as a rapid prototyping technique, we are able to obtain personalized artefacts with different qualities, affordances, and experiences.

Crafting as a hybrid practice and collaborative embodied experience

As the case study demonstrates, HMS are made of components – layers or building blocks – that have physical and interactive natures, latent and dynamic qualities, material- and technology-based elements. Due to this complexity, ICS materials and HMS are situated at the intersection of material science, interaction design, and design. This position implies specific knowledge and skills needed to design *with* and *for* these materials. For instance, to make the whole system function, programming skills are required to make the technology working, material-making skills to craft the material samples, and design skills to integrate them into a system. This has implications for defining design processes and fabrication techniques to ideate and prototype such materials.

Collaboration within a mixed research and practice group is a valuable resource for many reasons, especially for learning from one another and merging skills and knowledge to tackle multidisciplinary challenges (Groth et al., 2020). In this case, thanks to the multidisciplinary structure of the experimentation, the research team has expanded its knowledge in areas that are not usually tackled together. In particular, we find that the practice of cooking can enhance a shared experiential knowledge of materials. Indeed, the intrinsic and shared familiarity with the process of cooking facilitates a visceral creation process and an intuitive dialogue between the team members with different background, and types and levels of their expertise and knowledge. Following recipes and instructions promotes a whole bodily experience in which new knowledge and skills flourish (Sutton, 2018). In cooking, creativity is activated and embodied knowledge is revealed (Baurley et al., 2020) as designers deal with recipe instructions and personal preferences, observe results, and make extemporaneous creative decisions.

Our experimentation highlights the collaborative aspect of embodied experience. Indeed, it emphasizes the relationships between individuals and materials, and the impact of the context and the researchers involved on the creation and transmission of knowledge. Through collaborative crafting, the research team has acquired and expanded the basic knowledge, potential and limitations of bio-based materials, laser cutting and engraving, and LED integration and programming. In this space, design emerges as an experimental and interdisciplinary dialogue involving the analogue – for instance, the shared practice of cooking bioplastics – and the digital – laser cutting and engraving techniques and actuators programming.

Enabled and implied experiences

HMS and ICS materials are enablers of novel and meaningful materials experience, as a combination of the expressive-sensorial characteristics, meanings, emotions, and actions elicited by their material components and interactive behaviours. During the experimentation, we have recollected and analysed our personal experience emerging from interacting with these materials through our self-observation and discussion, following a first-person observation and self-reporting approach. To articulate, label, and link our observations, we applied in an intuitive, rather than systematic, manner the four levels of the materials experience framework (Giaccardi & Karana, 2015): (a) sensorial (i.e., how materials are sensed), (b) affective (i.e., emotions elicited by materials), (c) interpretive (i.e., meanings evoked by materials), and (d) performative (i.e., actions prompted by materials).

Among the main findings, the relationship and distinction between temporal and static expressions stands out. When the material sample does not perform a temporal behaviour, our observation reveals its considerable similarity with traditional bioplastics. This resemblance arises primarily from the sensorial experience tied to the material used to encase the technology – i.e., the one we first experience with our senses. The same implication regards the emotions and meanings elicited, which depend on our previous experience and familiarity with the material. Conversely, the sample's light-emitting behaviour exerts a significant influence across all experiential levels. For example, this temporal expression enables our emotions of surprise, fascination, awe, and contentment. As a result of the presence of static and temporal expressions, the samples generate experiential tension and contradiction; we can perceive them simultaneously as familiar, traditional, and natural – for their appearance – and strange, technological, and artificial – for their behaviours. Additionally, the occasional folding and shrinkage occurring in the samples over time introduce a slower and unpredictable temporal expression. The resulting layered and complex temporal forms contribute to our deeper emotional connection with the samples.

Expanding embodied knowledge: designing artefacts in a collaborative workshop

Applied to an educational design workshop (Parisi et al., 2021), our experimentation offers us an opportunity to share our knowledge with participants using samples, recipes, and tutorials. The developed crafting procedure and methodology based on the combination of bioplastic making, customizable digital manufacturing, and sensor and actuators embedding allow for the ideation of tangible artefacts. Access to the crafting methodology, such as laser-cut wooden frames and laser-engraved textured plastic sheets in various dimensions, enables the participants to experiment with the first bioplastic samples. After some iterations, they can start designing their own frames for form-making, surfaces for texture-making, and recipes for material expression. The participants are able to create new recipes by changing the ingredients' proportions and adding fillers (e.g., powders and pigments), exploring different properties of bioplastics, including mechanical (e.g., elasticity, stiffness), optical (e.g., transparency, translucency, opaqueness), and physical (e.g., texture) properties. They can also add interactive behaviours to bioplastics using digitally fabricated supports and embeddable electronics, e.g., touch sensors, LEDs, and an Arduino Mini board. The combination of DIY bioplastics as an easily customizable material and digital fabrication as a rapid prototyping technique support the participants in achieving personalized, tangible interfaces for unique experiences (Figure 14.6). Finally, the potential of bioplastics to embed technologies can be exploited. In most cases, the participants explore the interplay between technology, materials, and shapes using the concept of light. The light-emitting behaviour and the material qualities are intrinsically dependent and inform each other, while the texture enhances the interaction between the light and the material. We realize the value of the hands-on and extensive experimental process as being particularly informative. Thanks to the collaborative setting of the workshop, the participants master the basic knowledge, potential, and limits of bioplastics, understanding some unconventional application potential of

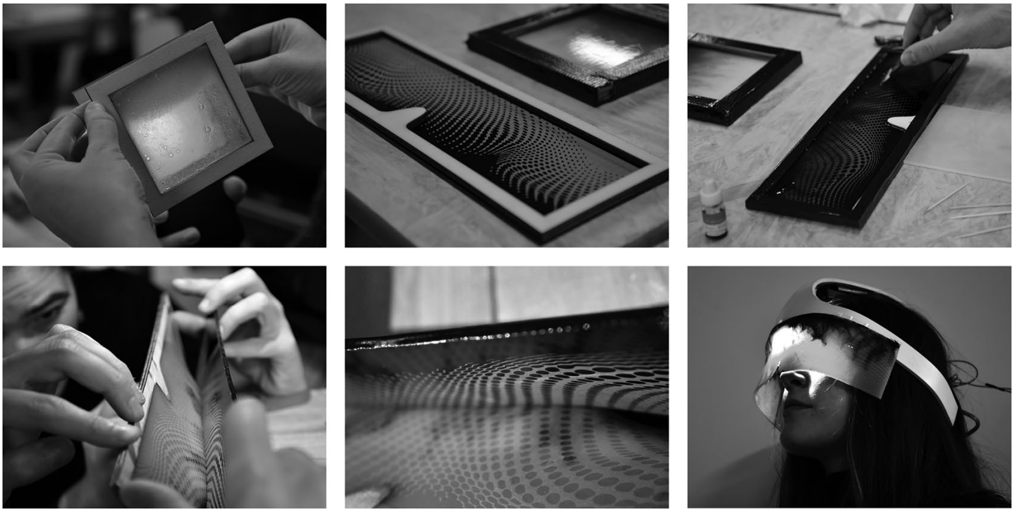

Figure 14.6 The methodology applied in a design workshop. Participants achieve personalized shapes and textures through laser-cutting and engraving on moulds, ultimately shaping a conceptual product prototype. Photographs by Laura Varisco.

digital manufacturing technologies. In doing so, they learn and first-hand experience that integrating electronic components into a prototype presents unexpected complexities. This embodied experience of the participants dealing with areas that are not usually tackled together is possible thanks to the multidisciplinary and collaborative setup of the experimentation.

Our experimentation and the organization of a design workshop have allowed us to produce physical results in the form of samples and prototypes, and ultimately to make direct observations on ICS materials and HMS. However, one of the main limitations we have encountered in the research is the difficulty of seamlessly integrating technologies into the material due to the limited available resources and the low-tech DIY techniques chosen for the experimentation. We have often opted for a "simulation" approach to overcome these obstacles. In fact, most of the samples and prototypes we have developed do not integrate technologies correctly or seamlessly. Therefore, some bulky technological components such as Arduino boards and batteries are assembled to the prototype in a removable or "quick-and-dirty" way, put close to the materials without an actual integration, or hidden in a case.

However, these prototypes should not be considered as completely functioning or feasible products ready for use but as demonstrators of possible future materials and platforms for speculative and critical thinking. From this viewpoint, the inherently underdeveloped and open-ended nature of the material forms encourages imagination. This approach facilitates envisioning potential future solutions detaching from the current stage of materialization that can be achieved today. It allows for novel ways of envisioning material-based futures and new experiential learning practices. From a technical perspective, the prototypes can easily be adapted to new configurations and technologies, becoming a platform for cultivating material thinking through bioplastic cooking and digital fabrication in collaborative and experiential learning settings.

Conclusion

This chapter has explored hybrid craft practices, their impact on designers, and the integration of technology and materials to create novel materials experiences, through a case study of augmented bioplastic. The craft method involves DIY bioplastic cooking, smart components programming, and digital fabrication, revealing intertwined relationships between material qualities, form, and technology programming. The collaborative aspect of the embodied experience has been highlighted, as crafting becomes a space for interdisciplinary and material dialogue involving analogue and digital elements. The collaborative experimentation and the workshop have demonstrated the potential of HMS and ICS materials to enable novel and meaningful materials experiences.

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